AGRICULTURAL ENGINEERING

FEBRUARY · 1948

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

EDITORIAL

Soil Conservation Research

THE round-table discussion during the Winter Meeting of the American Society of Agricultural Engineers at Chicago in December, on the effects of soil conservation practices on water runoff from agricultural land, brought up an important point. Every member of the A.S.A.E. and of any similar professional group will agree that engineers and other technicians must have basic information to perform properly their function. Research in the field of soil and water conservation and water flow retardation has from its very inception been handicapped by inadequate funds.

The soil conservation program which began on an unprecedented scale in 1934 was preceded by only two or three years of preliminary research, much of which constituted demonstrations designed to make the public aware of the erosion menace. By 1936 when the first appropriation for research in the Soil Conservation Service was made, the action program was greatly expanded and the flood control program was added. It naturally took some time to evolve a satisfactory research organization and to train the highly technical personnel needed for this work. Meanwhile the action program continued to expand and the problems for which immediate solutions were required multiplied rapidly. As a consequence, much of the research facilities and efforts were and still are directed to the quick solution of practical and more or less local problems.

The constant pressure for information coupled with inadequate funds made it impossible to completely analyze and publish the results. Neither was it possible to obtain sufficient information of a fundamental nature and of universal value. The need for fundamental research became evident with continued expansion of the action programs in soil conservation, drainage, irrigation, reclamation, and flood control. Without knowledge of basic principles, results obtained in one location cannot be applied to another.

The leaders in conservation and in agricultural engineering expected, and justly so, that, with the value of a sound research approach to critical problems so well demonstrated by the war, ample facilities would be made available to meet the immediate growing needs of the action programs to obtain the necessary fundamental knowledge. The reduction of funds for the 1948 fiscal year was therefore a severe blow to all who believe that action programs must be based on results of properly conducted research.

Agricultural engineers have always fully supported the maximum effort in combating erosion, floods, and the misuse of the land. They have also advocated expansion of agricultural production through drainage and irrigation. This they did as citizens "qualified to judge such matters." As responsible members of the profession they cannot remain complacent when they are denied the opportunity of constantly improving and adding to the basic information necessary to perform these difficult tasks. Agricultural engineers and others who, day in and day out, must design conservation structures, develop practices, plan drainage and irrigation projects, estimate effects of conservation practices on floods, and plan measures for erosion prevention and runoff and waterflow retardation, cannot agree that a reduction in conservation research can be effected without ultimate serious harm to the cause of soil conservation and proper land use.

It seems unrealistic and unwise to curtail research while action programs continue to expand. The number of unsolved problems and their complexity increase with the increase of the scope of the action programs. Facilities for research must be scaled to the need for information and must be timed to the expenditures for action programs.

The research division of the U.S. Soil Conservation Service is the only federal agency directly authorized to conduct research which must support not only the action program of the Soil Conservation Service, but also the far more extensive programs of the U.S. Production and Marketing Administration and of the U.S. Bureau of Reclamation. Funds now available for SCS research largely support the agricultural hydrologic research being conducted in the various state agricultural experiment stations. The present appropriation for SCS research is but a fraction of 1 per cent of the total federal appropriations for these action programs. The conservation payments on farm ponds for 1936-1945 amounted to slightly over 82 million dollars (546,814,317 cubic yards at 15 cents). Yet not a single dollar was made available prior or even during this period for research on the many difficult technical problems involved in a nation-wide pond-building program. The disproportionate number of unsatisfactory ponds attests to the urgent need for such research.

It is such facts as these together with those brought out in the report from the Committee on Agricultural Hydrology that cause us to view with alarm the trend indicated by the recent reduction in funds available for conservation research. Already this action resulted in serious damage. Without adequate support, engineers, scientists, and technicians whose training took several years and large amounts of public funds will leave this field of research to accept employment in other fields where their highly specialized training and experience can seldom be fully utilized.

EDITOR'S NOTE: The contributions to the round-table discussion referred to in the opening paragraph will appear in AGRICULTURAL ENGINEERING for March.

New Model Cows

RECENTLY we have noted reference by some dairymen and farm managers to "annual models" and "cow-power" ratings, with indications that they are thinking in quantitative terms on biological efficiency or output per unit of investment, feed, and operating cost. They promise new model cows with increased over-all efficiency.

This suggests that engineering habits of quantitative thought, and the engineering viewpoint on farm production operations are penetrating the consciousness of agricultural people to a greater extent than we may realize. It was bound to happen. They like the results of engineering in their farm buildings and equipment. They like its influence on their capacity to accomplish work and get results. They are beginning to appreciate the extent to which their own low-cost, quantity-production problems involve engineering management and operating principles, as well as engineered structures and equipment.

It is going to be easier in the future for engineers, agricultural scientists, and farmers to understand each other. They will all be using some of the engineers' lingo. In some ways this will ease the work of the agricultural engineer. But he will have to be more sure of his engineering than ever to satisfy and hold the confidence of the farmer who is well informed on possibilities and actual results in engineering performance; the farmer who wants an engineered unit to fit into an engineered farm production setup.

Quantitative Measures of Hay Quality

WHAT is good hay? A number of engineers concerned with improving methods and equipment for handling hay are getting quite impatient for a more explicit definition than is now available. It appears that it will only be obtained by close cooperation with animal nutrition specialists and by letting them know quite specifically what is wanted.

By way of review, the engineering requirement for evaluation of hay might be summarized about as follows:

A definition in general terms, based on a sensitive sixth sense of the livestock feeder, is not enough. What is needed is a definition based on measured reactions of various types and breeds of animals to specific physical and chemical characteristics found in various combinations in hay from various source plants, soils, stages of cutting, methods and conditions of harvesting, and conditions and duration of storage.

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VOL. 29 FEBRUARY, 1948 No. 2

Types and Performance of Farm Grain Driers

By W. V. Hukill

MEMBER A.S.A.E.

BEFORE attempting to classify driers by types, I would like to review some of the factors and limitations that apply to grain driers in general. Practically all types of grain driers that have been used for farm drying use air to carry off evaporated moisture. Since air is necessary to carry off the moisture, the amount of heat which it carries off may be an important factor. In evaporating moisture from grain it is necessary to supply the heat required for evaporation. Evaporation from a free water surface requires in the neighborhood of 1000 Btu per pound of water evaporated. The exact amount of heat necessary depends upon the temperature at which evaporation takes place. When the water is evaporated from grain instead of from a free water surface, even more heat is necessary. In any case, the amount of moisture evaporated from the grain is proportional to the amount of heat delivered to it. In all cases where artificial heat is supplied, the percentage of heat supplied that is used for evaporation is an important factor in the efficiency of the drying process. When the exhaust air leaves the drier warmer than the atmosphere, the utilization of the heat for drying is less than 100 per cent. This is usually the case when artificial heat is used.

In any type of drier the character of the grain being dried sets certain limitations to the performance of the drier. Small seeds which give off moisture readily can be dried more quickly than the large ones. This does not mean that they use less heat in drying, but that they are capable of absorbing heat and using it for evaporation more rapidly. The moisture in ear corn must travel a considerable distance within the ear before it can escape to the air and, therefore, drying is essentially slower with ear corn than with small grains. The higher the temperature, the more readily the moisture leaves the grain. At any temperature there is a minimum period of exposure that is required to effect a given reduction in moisture content. The moisture cannot be driven from the grain at a faster rate unless the temperature is raised. For this reason, the maximum capacity of a drier can be increased by operating at higher temperatures. The maximum temperature that may be used without injury to the grain depends upon the kind of grain and the use that is to be made of it. In general, for any grain that is to be used as seed or if subsequent germination is important, more or less definite temperature limitations have been established. Temperatures above about 110F are usually considered to be unsafe for drying grain to be used as seed. There is little information available on the temperature limit for grain that is to be used for feed. It is known that livestock will eat grain dried at much higher temperatures, and it is common for commercial drying plants to operate at 200F or above. Wet millers of corn have found that corn dried at temperatures above 120 to 130F is difficult to mill. Wheat millers object to wheat dried at high temperatures and describe the effect of such drying as "case hardening" of the wheat berry.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Farm Structures and Rural Electric Divisions.

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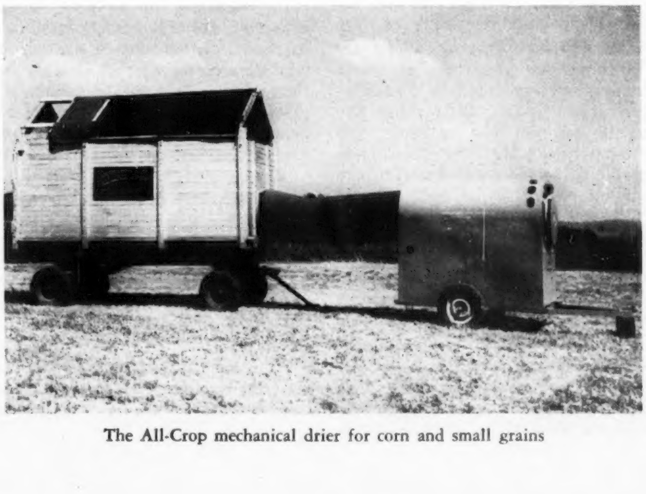

The All-Crop mechanical drier for corn and small grains

Operators of rice driers have observed that if drying is permitted to take place too rapidly the rice grain will be checked. Such checked grains will be broken during the milling process. Consequently in drying rice the driers are sometimes operated so that only one or two per cent of moisture reduction is accomplished in one drying operation. Since it usually is necessary to take out more moisture, the rice commonly is put through the drier again two or three times with a tempering period between runs through the drier.

Farm grain driers can be classified as natural or mechanical. Natural driers include ventilated bins and corn cribs which depend for their performance on contact with atmospheric air having a relatively low humidity. The wind is depended upon to pass the air through the grain. For shelled corn or small grains, ventilated bins depending upon the wind for air movement are effective only in dry weather and are used only in relatively dry climates. Corn cribs, which may be classed as natural driers, are effective in moderately dry climates. Corn is harvested in the fall, and since fall and winter temperatures are low, a period of several months may be permitted for getting the grain down to a low moisture content. When corn is picked with excessively high moisture or in regions where winter temperatures do not go low enough to stop insect and mold activity, natural drying in a corn crib may not be adequate for preserving the corn.

Mechanical driers, using forced ventilation with unheated air, usually consist of a motor and fan attached to a storage building in such a way that natural drying can be speeded up during periods of favorable temperature and humidity. By selecting the periods of operation, ear corn or shelled corn or small grains can be dried effectively by circulation of atmospheric air. However, such driers are limited in their performance by depending upon atmospheric temperature and humidity. If rapid drying is desired, ventilation with unheated air may not remove moisture quickly enough. However, with ear corn particularly, the equipment may be operated to advantage during periods of high humidity even though no drying may be accomplished. When the temperature and humidity are high and there is danger of heating, movement of air through the corn will keep it cool even though little, if any, drying is done.

Grain driers using forced circulation of air and artificial heat are coming into more general farm use. Forced, heated air may be applied for

drying in several different ways. Perhaps the most common is the batch drier in which dry air is forced through the grain and exhausted directly to the atmosphere after a single passage through the grain. For small grains, other processes are sometimes used. In commercial driers and some farm driers the grain flows continuously through the drier. In the continuous drier, damp grain is fed into the drier in a continuous stream and removed continuously after drying. To take full advantage of the process of continuous drying, it is desirable to have the grain flowing in the direction opposite to the flow of air; that is, the dry air comes in contact with grain almost ready to leave and passes through successively wetter layers, leaving the drier at the point where the wet grain enters. For ear corn, continuous driers have not been used because of the difficulty of getting ear corn to flow.

A semicontinuous process has been used in seed corn drying plants for ear corn. In this case, batches of ear corn are put into different compartments of the drier and the air travels from one compartment to another, passing through two to four batches of corn before leaving. This has some of the advantages of the continuous-flow process, although the corn is handled into and out of the drier in batches.

A modification of the simple batch process is to have all of the grain in a single compartment and pass the drying air through the grain in one direction, say, from bottom to top, for a certain period and then reverse the direction of air flow by making it move from top to bottom for completing the drying. This process is not used very generally, and I have little information on its effectiveness as compared with the simpler one-way drier.

MOST COMMON TYPE DRIER HAS LIMITATIONS

The most common type of drier, the one in which air is passed in one direction through a batch of corn until drying is completed, has some basic limitations. In such a drier the grain near the air inlet dries more quickly than that near the outlet. Also, during the latter part of the drying period, some of the air must leave the drier in an unsaturated condition, thus failing to utilize part of the available heat. This may occur throughout the drying period, or it may occur only during the later stages. These two limitations, non-uniformity of drying and failure to use all of the available heat, are characteristic of this type of drier.

The drying may be made to proceed more nearly uniformly throughout the mass of grain by increasing rate of air movement, but this is done at the expense of further reduction in heat utilization. The efficiency of heat utilization may be increased by reducing the rate of air movement, but this, of course, increases the variation of drying in different parts of the grain. It is characteristic of this type of drier that under most conditions of use uniformity of drying can be improved only by sacrificing efficiency in the use of heat or increasing the drying time.

Obviously, in actual operation there must be a compromise between uniform final moisture content and economy in fuel supply. In some cases, particularly when only a small amount of moisture needs to be removed, the cost of fuel may be less important than uniform drying, in which case it will be desirable to use the relatively large amount of air and get more nearly uniform drying at the expense of greater fuel consumption. In the case of ear corn drying, particularly when the initial moisture content may be 30 per cent or more, the amount of fuel required for evaporating the corn moisture is so large that it may be desirable to sacrifice some uniformity in final moisture content in the interest of saving fuel. This is particularly true if the dried corn is to be left in the crib for several months after drying, in which case the corn moistures will tend to equalize, the very dry corn absorbing moisture from the atmosphere and the wettest corn probably drying some.

In ear corn driers of this type there is always a question of the most satisfactory temperature for drying air. In general, particularly if corn is very moist, it can be dried most economically of fuel and power at the higher temperatures. However, the use of high-temperature air for drying will in some cases cause mold or other damage in the corn that dries last. This will happen if the total amount of moisture to be removed from all the grain in the bin is large, relative to the rate of heat supply, that is, if it takes a long time to complete drying. Such damage will not occur if fuel is used fast enough to complete the drying in a few days. At lower temperatures the dried corn will tend to be of more uniform moisture content.

Since the drying rate of ear corn or the rate at which moisture can escape to the air increases rapidly with higher temperatures, it is usually uneconomical to dry with artificial heat and use very low drying temperatures. No definite temperature limit can be set below which artificial heating is uneconomical, but if the heated air is at a temperature less than 50 or 60F, the heat from the fuel will usually not be used to very good advantage. Furthermore, at such low temperatures it will take a long time to get the corn dried.

There may be some conditions under which drying periods of three to four weeks may not be objectionable, but in the usual case drying within four to six days, or less, is much more satisfactory. The upper limit of temperature that can be tolerated depends upon the use to be made of the grain. Obviously, if it is to be used for seed, drying temperatures should be limited to not more than 110F. Corn that is to be used for wet milling should probably not be exposed to temperatures higher than about 130 F. There is some evidence that temperatures in the neighborhood of 200 F have an injurious effect on corn to be used as feed, but this point is not well established. We are particularly in need of experimental results showing the relative effects, if any, of drying grains, particularly corn, at various temperatures from 100 to 200 F, or more.

Many driers of the type we are discussing are so constructed that the products of combustion of the fuel are discharged directly into the drying air and passed through the grain. In the case of seed corn drying, this practice is quite general and no harmful effects have been observed when liquid or gas fuels are used. For purposes other than seed, there is the possibility that the products of combustion may carry some unburned fuel and deposit it on the corn. However, experience does not indicate that this practice is harmful even for corn to be used as feed. Small amounts of unburned fuel deposited on a small amount of corn being dried do not seem to be serious. We have heard reports of livestock refusing to eat corn most directly exposed to products of combustion from burning oil. But on the whole there seems to have been very little difficulty from this source.

UTILIZING ALL THE HEAT OF COMBUSTION

Driers which use the products of combustion in the drying air have the advantage of simpler construction than those in which the products are exhausted through a stack and the heat is transferred through a heat exchanger to air for drying. In addition, practically all of the heat generated by combustion goes into the drying air in a direct fire drier, whereas the efficiency of practically all heat exchangers will probably not exceed 70 or 80 per cent.

In most grain driers using forced-air circulation, the air is discharged from the fan and eventually passes through the corn. In some the air may be drawn through the corn and into the blower. It is usually more convenient to have the grain on the discharge side of the fan instead of on the intake side. The choice of whether the air is pushed through or drawn through the grain should be made on the basis of convenience, safety, and economy in the equipment, since there is no evidence to show that there is any difference in effectiveness of drying between air movement by suction and by pressure.

There are a number of special types of driers, any of which may eventually be developed to the point of common use, but so far their use is limited. These include driers in which the heat is supplied by radiation with infrared or other parts of the spectrum, those in which the heat is supplied to the grain by electrical induction, and those in which the heat is supplied to the grain by radiation of heat or by conduction of heat. One drier of this type was developed by Kelly. In this case the grain is heated in a drum and passed on to a drying compartment through which atmospheric air is blown. This drier operates continuously and as much as 2 or 3 per cent moisture can be removed in one passage through the drier.

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The Case Against Non-Metallic Sheathed Cable

By Glenn Rowell

NON-METALLIC sheathed cable was introduced as a wiring material following World War I, and from what one can learn from persons active in the wiring materials branch of the electrical industry at that time, the advertising campaign conducted to gain recognition for this cable presented one of the most controversial subjects ever to confront the electrical code committee. After considerable maneuvering during which many skulls were cracked, figuratively speaking, the Committee finally agreed to recognize it as an approved wiring material and the 1928 edition of the National Electrical Code contained the first regulations governing its use. The pros and cons of that battle are still a lively subject for an evening spent with one of the persons on the committee at that time. Many of you may remember the elaborate brochures prepared and distributed throughout the country extolling the virtues of this new wiring material.

Non-metallic sheathed cable has become an accepted wiring material capable of giving safe and satisfactory service when used as it was originally intended, for the wiring of dwellings. There are today countless thousands of installations in homes all over this country and the experience has not been bad. In fact, even large cities have permitted its use in dwellings, notably Detroit and Philadelphia. Today there are twenty-five manufacturers of this cable listed by Underwriters' Laboratories.

When the Rural Electrification Administration began its program of furnishing electrical energy to rural America, we in the electrical industry and those responsible for the excellent idea of rural electrification were in reality asleep at the switch. We talked only of replacing the kerosene lamp and lantern, and no one outside of your society made any attempt to discover just what electricity might mean to the American farmer. Actually there were REA employees traveling about the country arranging meetings of farm groups and advising them that they could wire the average farm for not more than $65. REA engineers actually laid out distribution lines, many of which were as much as forty miles or more in length (some almost eighty miles in length), and hung 1½-kw transformers to serve the average farm. All this is definite proof that all we expected to do was to replace kerosene lamps and lanterns.

The electrical contractor found a most undesirable condition when he became interested in farm work because of the low-cost ideas that had been broadcast. Many in fact refused even to take part, with the result that a great many farms were wired by persons and firms neither qualified nor capable of doing either a safe or an adequate job. Being faced with the necessity of keeping costs down, it was deemed necessary to use the cheapest materials available. Non-metallic sheathed cable being low in cost and easy to install, as it required fewer man-hours per outlet than any other wiring material, was naturally selected as the material to use on American farms—this in spite of the fact that every edition of the National Electrical Code from 1928 through 1940 specifically prohibited its use in corrosive or damp locations. Both the electrical industry and REA should have established fact-finding committees to determine the proper methods of wiring farm properties. There were enough farms then being served by private utilities to furnish all the evidence necessary to convince any thinking person of the need of developing special wiring materials and devices, and also of the need for both heat and power in addition to light.

You can hardly blame the farmer today whose opinion of both the REA and the electrical industry sinks lower every time he looks at the cable in his barn, which has, snakelike, shed its outer coat, or at the boxes and cabinets which are red with rust, or at the wiring devices now supported only by the conductors attached to them. Then to rub salt in these wounds, the 1947 edition of the National Electrical Code states that outbuildings on farms should not be considered as damp or corrosive locations when considering whether or not you can use non-metallic sheathed cable in them. How the persons responsible for this change in the Code text ever decided that cattle barns were neither damp nor corrosive, I do not know. It is certain they did not visit many during the winter months, but possibly they found it expedient to do so when they learned of the hundreds of thousands of farms wired with non-metallic sheathed cable. Our latest census in Minnesota alone indicates that we have some 130,000 farm properties connected and most of them are wired with this cable. REA now serves 2 million customers, 1½ million of which are farmers.

When this rural wiring program got under way, I was asked to determine the possible fire hazards which might result from the project. As a result of several weeks spent in rural Minnesota, I requested and received permission to prepare a simple set of wiring standards which might be understood by the average layman, as I actually found farms wired with bell wire. Five complete farms were found wired with copper-plated steel telephone wire and the largest conductor even between buildings was about No. 16. Every one of the REA cooperatives I discussed this problem with seemed willing to adopt some wiring regulations which would keep their members from being bilked too badly. In an attempt to accumulate data, I obtained every different type of wiring material or device I could get my hands on and placed them in cattle barns near Minneapolis; and there I, too, missed the boat, because it so happened the barns I had access to were all well ventilated and did not get as wet as the majority do. Certain facts were discovered, such as the need for prohibiting the placing of any ordinary wiring material or device against the inside of any outside wall. In 1936 the first set of standards was prepared in mimeograph form and presented by our bureau to any REA cooperative or electrical contractor that wished to use them. The following year the electrical industry succeeded in convincing our state legislature of the need for control over electrical installations, and we had a state-wide electrical licensing law enacted. The mimeographed standards were then published in pamphlet form and most of our farms were wired to conform to those regulations.

The original standard required the use of non-corrosive boxes and cabinets, and if steel were used they specified that it must be galvanized or plated with a corrosion-resistant finish. The manufacturers refused to make special equipment for use only in Minnesota, so we had to give up our battle and accept the painted cabinets even though we knew they could not stand up. As far as I have been able to determine, no other area even attempted to force the industry to produce special corrosion-resistant equipment or wiring materials, so we like everyone else accepted those materials and wiring devices designed for urban use. As a result, we face the problem now of rewiring these farms. Most buildings used to house livestock during cold weather must be rewired for two reasons: first, to remove the hazardous conditions, and, second, to provide adequate capacity. Not too long ago the REA hired a large number of persons and kept them busy attempting to build up load. Today that program has been reversed as there is not sufficient energy nor distribution capacity available to supply the existing load. As an example, I have some preliminary figures released by the Northern States Power Company from a field survey they have begun, to determine loads which they may expect on the rural lines served by them. On one line serving 115 farms all located in a poor farming area adjacent to Minneapolis, they found that 98 per cent of these customers pumped water with electricity, 78 per cent had electric refrigerators, 67 per cent had electric milking machines, 42½ per cent had electric ranges, 31 per cent used deep-freeze storage boxes, 22 per cent had 10-gal dairy

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This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Rural Electric Division.

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water heaters in their milkhouses, 19 per cent had storage-type electric water heaters, 7.7 per cent had electric milk coolers, one used an electric arc welder, and one had installed a barn cleaner. Most of this load has been added during the time when electrical appliances have been almost impossible to get. A year ago an implement dealer in a small village sold and delivered 32 corn elevators and only one of his customers had adequate wiring at the corn crib to serve the 220-v, single-phase motor that operated the elevator. I have stressed this inadequacy which exists today in an attempt to hurry acceptance of the idea that we have to rewire the great majority of our farms. A few know of the hazards of life and property that are developing, but almost everyone today has begun to realize that the farm is actually an industrial establishment in addition to being a home. It has every right to expect electrical energy for heat and power as well as for light, but it cannot be made available until the individual farm is provided with an adequate and a safe wiring system.

It is impossible for anyone to say just how many fires have been caused by the deterioration of insulation. I hesitate even to guess the number we have had in Minnesota, although I can assure you that there have been a number of them, and we know the number will increase very rapidly unless this rewiring program gets under way very soon. We have started reinspection programs on several projects in our state during the past two years. On one project the inspector had to visit almost 200 farms before he found one that he felt could be considered safe. Out of over 1000 farms reinspected today the number considered safe is so small we are convinced that it is time for drastic action.

NON-METALLIC SHEATHED CABLE A SERIOUS PROBLEM

You may wonder why many of you have not learned of this problem before. We believe that we have in Minnesota the finest industry-wide electrical organization in the world. Our electrical inspectors association holds ten meetings each year; we have nineteen inspectors on REA projects alone, and everyone is a member of the state association. Each month these men bring in reports and samples from their projects so that we know just what is going on in every part of the state. As a result, we have been able to accumulate a lot of information about the problem with which we are confronted.

Non-metallic sheathed cable is proving to be our most serious problem because of the way it usually breaks down in out-of-sight places. Wherever it passes through drilled holes in the structural timbers of the barns or through partitions, especially those partitions that divide areas of different ambient temperatures, the destruction of the insulation takes place. If a cable is placed on the inside of an outside wall, or if it is so located that a cold blast of air from a doorway leading to the outside can strike it, this same destruction of the insulation takes place. Here, though, it can easily be seen and will no doubt be replaced before it can cause a fire in most instances. Within bored holes the story is different. Here the flow of air gradually deposits hay chaff and other dusts until the opening is practically plugged. Then during winter months this accumulation is soaked with moisture causing the braids to mildew and rot. Expansion and contraction of the building timbers also causes an abrasive action which hurries the process in many cases. Naturally the first current leakage is negligible; it gradually increases until the accumulation of chaff and other dusts is well carbonized, all this without the least danger of opening the circuit overcurrent protective device. Then it reaches the stage where it will either form a fire-starting arc or open the fuse or breaker.

This condition was first brought to light in Minnesota shortly before we entered the last war when it was impossible to expect our wire mills to do much about the design of a new wiring material. Since the war we have been promised that a new cable would be produced, and we understand that serious consideration is being given to various types of insulation which we know are capable of withstanding the effects of the corrosive conditions found in dairy barns. However, these new cables are not yet available and farms must be wired. Hence it is necessary that special precautions be taken to safeguard the dairy barn in which the non-metallic sheathed cable is used.

Minnesota is not the only area that has recognized this fact, as I have been informed that other areas too are demanding that special consideration be given. For instance, in the Province of Ontario the Hydro-Electric Power Commission has issued the following rulings:

1 Non-metallic sheathed cable in barns and stables shall not be run directly over windows, doors, or other openings in outside walls or where condensation is liable to form on the cable due to marked temperature differences, unless the cable be protected by a length of rigid metal conduit sealed at both ends with an approved insulating compound.

2 Non-metallic sheathed cable shall not be installed in root houses.

3 Non-metallic sheathed cable shall not be run in stairwells or through other openings, such as ventilating ducts, between the stable and the floor above unless enclosed in rigid conduit sealed at both ends with an approved insulating compound.

Just before the war the number of failures in Ontario was such that they were seriously considering issuing an order which would prohibit the use of this cable.

As a result of the reinspection program, several Minnesota REA projects have become so alarmed that their boards of directors have issued orders that no more farms will be served from their lines when non-metallic sheathed cable is used. That, gentlemen, is drastic action. I personally do not believe it will be necessary to take as big a step as that; however, it should convince the wire mills that they must produce a safer cable. Until that is done, we can greatly lessen the possible hazards to life and property by requiring that all buildings used to house livestock, if wired with cable, be wired in conformity with the requirements of the National Electrical Code and the following special precautions:

1 Non-metallic sheathed cable shall not be run on or attached to the inside of any outside wall unless placed on running boards which will assure at least two inches of air space between the board and the inside surface of the wall.

2 Where non-metallic sheathed cable passes through bored holes in timbers, the hole must be filled completely with an approved insulating compound, and where it passes through a floor or partition it shall be protected by nipples filled completely with an approved insulating compound.

3 After the cable is in place, it should be carefully painted either with an asphalt-base paint or any good grade enamel. This should preferably be done before the straps are fastened in place so that the cable can be coated on all sides.

SPECIAL PRECAUTIONS HAVE IMPROVED SITUATION

There are now a number of installations, made in Minnesota, on which the above-mentioned precautions were taken and so far these jobs are apparently standing the corrosive conditions perfectly as far as the cable is concerned. However, we are still faced with the corrosion of the steel boxes, cabinets, nails, and screws. We know that a properly ventilated barn reduced this problem materially. Possibly it is the job of the agricultural engineers to sell the American farmer on the need for adequate ventilation. I have been told that rural electrification will automatically assure the installation of adequate ventilation. Even if that is true, can we wait for it to happen? I do not believe we can.

Sometime ago we thought that porcelain wiring devices would be the answer, and frankly one manufacturer did produce a surface-wiring device which furnished satisfactory service when installed with corrosion-resisting screws. Since then several bakelite surface wiring devices have been placed on the market and used in large numbers. Our experience with them has been most disastrous. Moisture enters these devices bringing with it hay and grain dusts. Heat given off evaporates the moisture and gradually chars the dust until a conductive path is formed between two current-carrying parts having a voltage potential difference between them. The arc thus formed usually sets fire to the bakelite housing and sometimes even to the building. At one inspectors' meeting I asked for samples of these devices which had failed, and at the next meeting I was given over sixty by *(Continued on page 59)*

Building Safety into Farm Buildings

By C. L. Hamilton
MEMBER A.S.A.E.

FARM building standards can no longer be considered complete without making adequate provision for safety. They should be safe from injuries to people and safe from unnecessary fires. Many common causes of accidents around buildings have been known for sometime, but the same hazards continue to creep into design through oversight, neglect or indifference. It is unfortunate that accident hazards have been actually built into many farm buildings. The cost of one accident can more than pay for changes in design or construction which may prevent a disaster.

You will undoubtedly feel that many of the items which are mentioned in this paper are simple and obvious. You may also say they don't require much engineering — the farmer can figure them out for himself. I believe this is one of the main reasons why safety has not advanced as rapidly as other structural improvements in building designs. To cite one example, the detail for building a safe ladder to a hay mow is simple, but year after year agricultural engineers continue to put out farm plans without showing this detail, and year after year farmers continue to build barns with unguarded and hazardous ladders. Recently I went through nearly a hundred barns in northern Illinois, one of the best farming sections in this country, and only one of the barns had a ladder that would be approved by a safety engineer. Most of them were real accident hazards, and distinct inconveniences. Even the few that had stairways were not much better. Many large barns should have stairways, but it is difficult to install a stairway when the space required is not provided in the original plans. We cannot blame farmers for not having these structural safety features in their buildings as long as agricultural leaders continue to omit them from building plans and promotional material.

In any accident prevention program the removal of mechanical hazards is one of the easiest ways to secure results. It should always be given first consideration. It is easier to make a mechanical or structural change than to teach people to change unsafe habits that are deeply entrenched through years of use. Education to develop a safety consciousness is necessary, but by itself it seems to be a long hard road. Frequently it requires a mechanical rearrangement, a guard, or change in design to force people to change unsafe practices.

Safety must be considered in the original plans, in the materials of construction, in details, in lighting — yes, even in the color scheme and furniture arrangement. Safe structural features must be developed and included as an integral part of each plan. They must be practical so they are readily accepted as an essential part of the building. As leaders in the farm building field, you must accept this obligation as a part of your responsibility. Fortunately many safety features can also be distinct conveniences and time savers. Following is a review of a few of the safety features for some of the most important farm buildings; space will not permit a detailed discussion of them all.

Barn Hazards. In planning barn improvement it is some of the little things that make routine chores safe and easy. Many farmers spend one-half or more of their time doing farm work in and around barns. A 16-yr summary of fatal farm work falls in Kansas shows that about 50 per cent of them occurred in or around barns. A special survey in New York last summer revealed that almost one-half of all the farm accidents in the area studied occurred in the barns, and another one-third occurred in the barnyard or in other farm buildings. Defective design or neglected repairs did not cause all these casualties, but directly or indirectly structural improvements could have prevented a large portion of them.

Falls and falling objects cause many farm accidents; so barns should be checked for loose objects or things that lead to falls. High door sills should be removed or the entrance built up so that the sill does not project above the floor level. All floors should be solid, smooth, and continuous. If there must be a change in floor levels, ramps should be used. Plan special storages and orderly arrangements for alleyways or work areas that frequently become obstructed with feed, tools, harness, feed carts, or other obstacles. Don't let farmers work in the dark; see that dangerous corners and work centers are well lighted. Put light switches in convenient locations. Discourage the storage of loose materials overhead and see that forks, scrapers, and other barn equipment are kept in convenient places where they will not fall over. To encourage orderly housekeeping around the barn it is necessary to provide specific storage places for barn equipment.

Loft doors, feed chutes, and ladders are an accident menace in most barns. A well-constructed stairway provided with a hand rail and kept clean provides the safest and easiest passage to hay mows. Doors to the stairway should swing away from the stairwell. It is a bad practice to use stairwells as feed chutes because loose hay or straw make footing uncertain. Separate feed chutes that are guarded above the loft floor or to the top of the hay in a full mow are desirable in modern barns. When it is necessary to use a ladder, see that it is guarded and extended well above the loft floor. It should also have well-spaced stout rungs that are placed far enough from the wall for secure footing.

The safest and most convenient way to repair, adjust, or oil hay fork carriers is from a well-constructed platform at one end of the barn. Where the large hay doors are some distance from the floor, a good platform should be provided for servicing them. All elevated platforms should be equipped with a stout guard railing and accessible from a stationary ladder. The same treatment should be applied to feed bins or other accessories that involve climbing.

Farm Homes. As you consider the various details and requirements for remodeling and constructing farm

Left: This picture shows a safe barn ladder that extends well above the hay loft floor, and a well-guarded hay mow opening • *Right:* A well-constructed enclosed stairway, that has a hand rail and is kept clean, provides the safest and easiest passage to hay mows

This paper was presented at the 40th Annual Meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Farm Structures Division.

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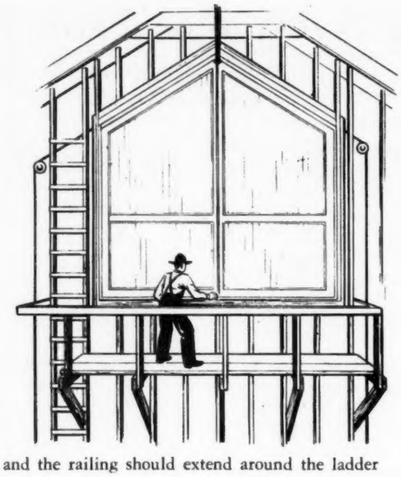


Above: Hay forks may be serviced easily and safely from this platform • *Right:* From this platform barn doors can be serviced safely. It should be built at least 2½ ft below the doors, and the railing should extend around the ladder

homes, you have probably given some consideration to safety because home safety has received more emphasis. The leading cause of accidental death and injuries among farm residents is home accidents. Available records indicate that falls account for about 39 per cent of the farm home fatalities, burns 25 per cent, firearms 7 per cent, poisoning 6 per cent, mechanical suffocation 4 per cent, and miscellaneous 19 per cent. Many special improvements are needed around farm homes to help reduce the high proportion of falls.

Stairs and Stairways. Stairs and steps if correctly built will prevent many falls. The builder should keep in mind that they will be used by old, by young, by those with failing eyesight and by the infirm. Then, too, most farm people have a lot of work to do and they are usually in a hurry. There are probably more unsafe stairways and steps in farm homes than any other single item. Basement and attic stairways are usually the worse safety offenders.

Every stair tread should be equal and at least 10 in wide. Risers should all be the same height and should not exceed 7¾ in. A fraction of an inch variation in the height of any riser or width of any tread has often caused bad falls. Nor should stairs be too steep; the proper slope is between 30 and 36 deg. Whenever possible, especially in long stairways, a spacious intermediate landing should be provided. It provides a pause that refreshes on the way up, and it also helps to break the worst falls that may occur near the top of the stairway.

Triangular steps or winders are often used to save space and many feel they have an esthetic appeal, but they are dangerous and should be avoided. If it is necessary to use winders they should be laid out so you have a tread of the normal width at the line of travel about 15 in out from the inside railing. At their narrowest end the tread should not be less than three-quarters of the normal width, so a reasonable toehold will be provided for children or others who hug the rail. In remodeling work, you will find some old stairs with winders clustered about the newel which cannot be altered. This condition can be made safer by adding a vertical handrail to the newel about 30 in long and projecting 4 or 5 in into the stairway. This will force users to walk on the wider portion of the tread and provide a hand hold for the entire turn.

Railings are another essential safety feature often overlooked. They create confidence and lend physical support where most needed. It is fully as important to install a railing for the basement, attic, and exterior steps as for the main stairway. Even front and back porches that are a foot or more above the ground level should have a railing. The severity of falls is not measured by the height of fall.

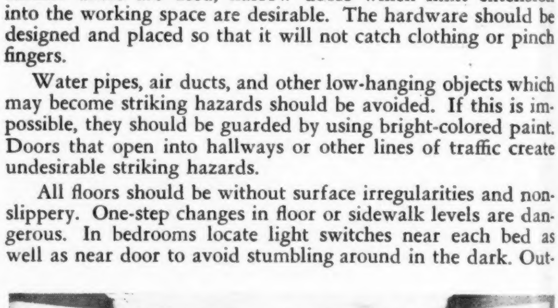
Consideration should also be given to other details in stair design that may save lives: The top and bottom approach to the stairway is a dangerous spot to watch out for. Never open doors directly down stairs or steps. If the upstairs hall is small doors to adjoining rooms should open inward, or there should never be less than a 30-inch minimum clearance from all doors at the head and foot of stairways. The first and last step should be clearly defined; a nosing of contrasting color to the tread provides a good marker. A lighter color is commonly recommended for the top and bottom steps of an attic or basement stairway. Provide lights with three-way switches on all stairs so they can be adequately lighted with a minimum of effort on the user's part.

Striking and Tripping Hazards. Don't forget to provide plenty of head room on stairways. The minimum clearance should be about 6 ft 8 in. Attic and basement stairs are just as important as the main stairway. The fact that they are not used as much is no reason for low headroom, short handrails, or steep design.

Other striking hazards can be eliminated by the use of vertical or horizontal sliding kitchen cabinet doors and rounded corners on counters and built-in furniture. If hinged kitchen cabinet doors are used, narrow doors which limit extension into the working space are desirable. The hardware should be designed and placed so that it will not catch clothing or pinch fingers.

Water pipes, air ducts, and other low-hanging objects which may become striking hazards should be avoided. If this is impossible, they should be guarded by using bright-colored paint. Doors that open into hallways or other lines of traffic create undesirable striking hazards.

All floors should be without surface irregularities and nonslippery. One-step changes in floor or sidewalk levels are dangerous. In bedrooms locate light switches near each bed as well as near door to avoid stumbling around in the dark. Out-



"A place for everything and everything in its place" helps prevent home accidents

lets for night lights wherever there are stair openings are also desirable.

Windows which can be cleaned and equipped with storm sash or screens from the inside eliminate a bad accident hazard, especially where the entire window area cannot be reached by a person standing on the ground or other solid footing.

Closet and Storage Space. The need for closet and storage space at the right place and designed for a specific purpose is gradually being recognized. Many household accidents from cluttered stairways, hallways, and other lines of traffic may be the result of disorderly housekeeping, but the real source of the trouble is usually inadequate storage facilities. In designing new homes or in planning remodeling work, a place should be planned for every household item like hats and coats, toys and games, housekeeping equipment, food, linen, toilet articles and medicine, clothing in current use, off-season clothing and equipment, and furniture, trunks, etc., not in immediate use.

Just a closet with four walls and a door is not enough. A closet should be divided with shelves or compartments so there is a definite place for each item. A place for everything and everything in its place is a sound safety motto. Adequate storage space for frequently used articles should be reached by a person of average height standing on the floor. Planning and designing suitable storage at the proper location for all the items used around the ordinary household requires a lot of forethought and ingenuity.

Even the common clothes closet which we find in homes today may need some overhauling. It is a customary practice to place one shelf about 2 ft from the ceiling. The original idea was probably to provide lots of depth for the big hat boxes women used to use. The old-fashioned hat boxes have practically disappeared but the closet shelf is still built the same way. To utilize the storage space fully, several small boxes or cartons, one on top of the other, will be found from the shelf level to the ceiling. When one is pulled out several others usually fall down. The spacing of shelves should be limited so storage items cannot be piled on top of each other. The widely used mirror cabinet over the lavatory is not a safe place to store medicine or poison. If special storages are not provided for dangerous items like poison or guns, they are usually found mixed in with other household items where children can easily get them.

POOR LIGHT COMMON CAUSE OF ACCIDENTS

Poor light is a common cause of accidents, besides being annoying and inconvenient. All storage spaces should be designed with adequate natural and artificial light whenever possible. If natural light is not feasible, at least electric lighting to protect persons from striking against protruding objects or groping in the dark should be provided. Closet illumination through the use of an automatic door-operated switch is an added safety feature.

Bathrooms. Bathrooms are supposed to be for cleanliness and comfort, but an amazing number of injuries — even fatal falls — occur in them. In planning a bathroom allow plenty of space between tub, toilet, and washbowl. Select a tub with a flat bottom. Provide handrails on the wall at the side of the tub. Make them long and run them diagonally or vertically up and down to provide support in a hurry whether sitting or standing and especially when entering or leaving the tub. Use recessed soap containers and provide safe disposal for razor blades. A shower stall and bathroom floor should have a non-slip surface. The bathtub should not be placed under a window which must be opened. Light switches and electrical appliances should be placed out of reach from lavatory or tub.

Safe Arrangements. The home design should permit free passage between rooms without congestion points. The location of windows, doors, or archways should facilitate convenient placing of furniture and unobstructed travel lanes. Doors should not swing into normal traffic lanes or strike other doors.

The location of any facility for which there is frequent need should be in the most accessible part of the house. Examples would be a lavatory and water closet on the first floor of a two-story house, telephone outlet in a central location, or a utility room on the main floor at ground level instead of in the basement.

Ample electric outlets should be provided where needed to eliminate use of long extension cords. Three-way switch controls should be used at the entrance and exit of the main room and for all stairways.

Farm Fires. Agriculture has a bad fire loss record, so fire prevention in new construction should not be overlooked. No one wants buildings with built-in fire traps.

Fire prevention should be considered in the spacing and general arrangement of farm buildings. It should be considered in the selection of the materials. Fire-resistant roof coverings are especially desirable. It should be considered in the construction of chimneys and fireplaces, in the installation of stoves and furnaces, and in electrical wiring. Firestopping is another important precaution in building. Check fires from using walls as readymade flues. This should be done at each floor level and where the roof rafters meet the wall. Fire-resistant interior finishes are also important. Such things as plastered furnace rooms, a double first floor, and a self-closing, metal-covered cellar door help retard fires. The fact that I have only mentioned these fire prevention features rather briefly does not mean that they are not important. Improved building codes have been an important factor in reducing fire losses in urban centers, and there is still a big field for similar improvement in agriculture.

Farm Grain Driers

(Continued from page 54)

Another drier was developed by Burkhardt in which the grain passes downward between hot water coils, while at the same time atmospheric air is passing upward through the grain and among the coils. This system also operates continuously and has the advantage that the heat is supplied within the bulk of the grain by the coils, and the air temperature does not necessarily drop in its upward passage through the grain as it does in the simple batch drier.

Still another general type of grain drier depends upon the absorptive action of some material put in contact with the grain or used to dry the air before it enters the grain.

The U. S. Department of Agriculture is purchasing seven driers for experimental use in cooperation with the state agricultural experiment stations. These use three different fuels and are of two different capacities. Some are equipped for direct heating and some have heat exchangers. These are all of the simple-batch drier type and are used for drying ear corn while in ordinary cribs. These driers have all been designed to heat the incoming air to about 70F above atmospheric temperature. Some of them are in operation and we expect to continue using them until spring to get further information on the important characteristics of driers. In addition several manufacturers have loaned driers for experimental use.

Safety in Farm Buildings

(Continued from page 56)

members who remembered my request. We, therefore, are faced with the need for devices constructed of non-combustible, non-corrodible material.

Porcelain may be the answer provided special units are made for farm use. In the first place, they must be so designed that the expansion of a moisture soaked building timber will not pull the supporting screws through the back of the box. Then, from the contractor's point of view, they should be more rugged to reduce the breakage now experienced during shipment and handling. Certain aluminum alloys are capable of withstanding the corrosive atmospheres found in these buildings, and now there are a few small manufacturers making aluminum outlet boxes. Possibly sufficient demand would increase its use by other companies. Certainly the potential market on our farms is too large to be ignored by the industry, provided the spokesmen for the rural electrical customers make a concerted effort to be heard.

When you consider the fact that every fire hazard is also a life hazard, that lives lost are lost forever, and that property burned is capital destroyed beyond replacement, I believe you will agree that it is time we do something.

Conservation Farming on a 100-Acre Farm Unit

By John R. Carreker

MEMBER A.S.A.E.

A FARM unit of 100 acres was established in 1941 on the Southern Piedmont Conservation Experiment Station of the USDA Soil Conservation Service at Watkinsville, Oconee County, Ga. The purpose of this unit was to gather data on conservation practices under actual farm conditions to supplement research findings under experimental conditions on the Station.

Much valuable information has been obtained from this farm during its six years of operation. The more pertinent findings are given in this report.

The basis of operation was a conservation farm plan to protect the land from erosion, improve the fertility of the soil, and provide adequate income for the farm operator and landowner.

Two mules with suitable equipment were used for the major work of crop production. Supplemental tractor equipment for work beyond the time and capacity of the mules was hired from off the farm when needed.

A tenant and his family, consisting of his wife, three small boys, and aged mother-in-law, operated the farm.

The 100 acres of land chosen for this unit closely represented farm conditions in Georgia. In 1940 the average size of all farms in the state was 109.6[1] acres.

The average Oconee County farm was 107.7 acres in size and contained 74.3 acres of cropland. This 100-acre farm had 69.0 acres of cropland, 10 acres open pasture, and 21 acres of woodland, homestead, etc.

The soils are of the Cecil and related series, which are the most common in the Piedmont soil province. They were low in fertility and organic matter as a result of past cropping and erosion. The degree of erosion varied from slight on the more level fields to very severe on the steeper areas. Approximately 11 acres had been taken out of cultivation in the past because of excessive erosion on steep slopes.

The land varied in slope from nearly flat on a few acres of hilltop to very steep near two small branches. The ravines in which the branches were located were quite narrow with practically no low-lying bottom land.

The field layout in 1941 is shown in Fig. 1. In accordance with Station results, the steepest slopes and terrace outlets were planted to the perennial legumes of kudzu or sericea lespedeza. A rotation containing small grains and annual lespedeza in sequence with cotton and corn was inaugurated on the remaining cropland.

All fields were terraced in 1941 with broad-base channel-type terraces and sodded terrace outlets. Kudzu was planted on 8.1 acres and sericea lespedeza on 2.9 acres of steep badly eroded land in field 5.

A 4-yr rotation was planned for the remaining 58 acres of cropland in fields 1, 2, 3, and 4. This rotation included: (1) small grain and annual lespedeza, (2) small grain and annual lespedeza, (3) cotton, followed by winter legume, and (4) corn.

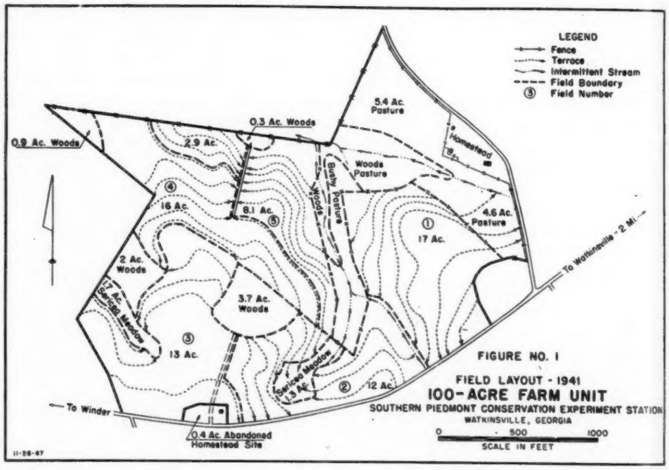
Fields 1 and 2 were in Korean lespedeza prior to 1941 and part of field 3 was in crimson clover. Therefore, the 1941 cotton was planted on field 1 after lespedeza, and corn on field 3 after crimson clover green manure. Oats had been planted by the Station on field 2 and wheat on field 4 in the fall of 1940. These crops began the rotation sequence described above.

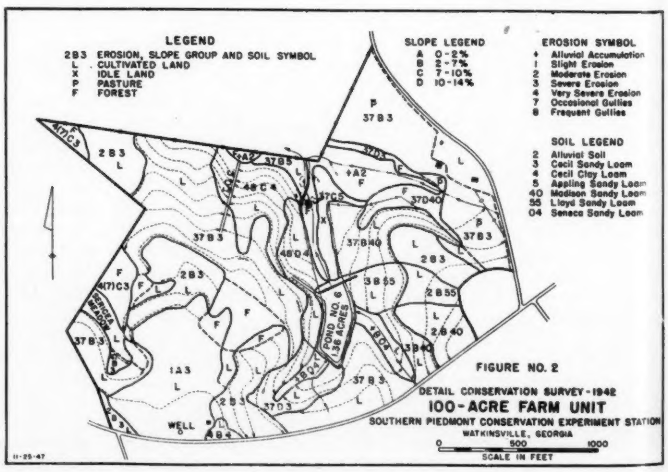
A detailed conservation survey of the land on this farm was made in 1942. The land use, degree of erosion, slopes and soil type recorded in this survey are shown in Fig. 2. On the basis of this survey, the land capability classes were determined as shown in Fig. 3.

These capability classes were then used as a basis of field arrangement for crop rotations. The fields were renumbered in accordance with the land capability class as shown in Fig. 4. Changes in cropping were made along terrace lines nearest the capability change.

The small grains planted in the fall of 1943 and the row crops of 1944 were arranged to give the following rotations:

Land class I: 8.2 acres with corn continuously with volunteer crotalaria.





Top: Fig. 1 • *Bottom:* Fig. 2

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Soil and Water Division.

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[1]U. S. Census of Agriculture, 1945, vol. 1, part 17, Georgia.

Land class II: 18.6 acres with a 2-yr rotation of (1) oats-Kobe lespedeza and (2) cotton or corn.

Land class III: 22.4 acres with a 3-yr rotation of (1) wheat-Kobe lespedeza, (2) wheat-Kobe lespedeza, and (3) cotton.

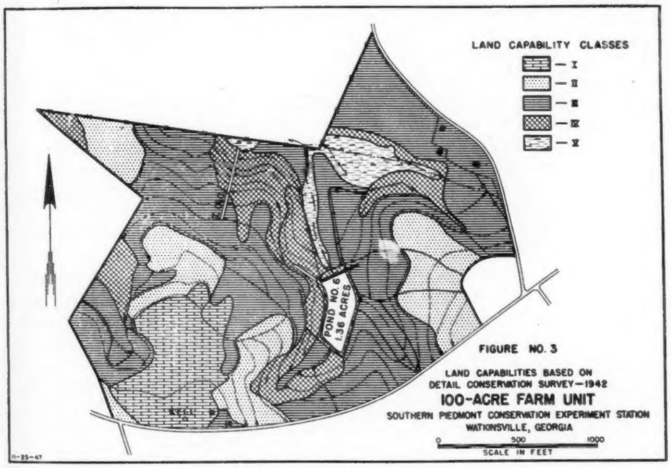
Land class IV: 19.9 acres with continuous kudzu or sericea lespedeza.

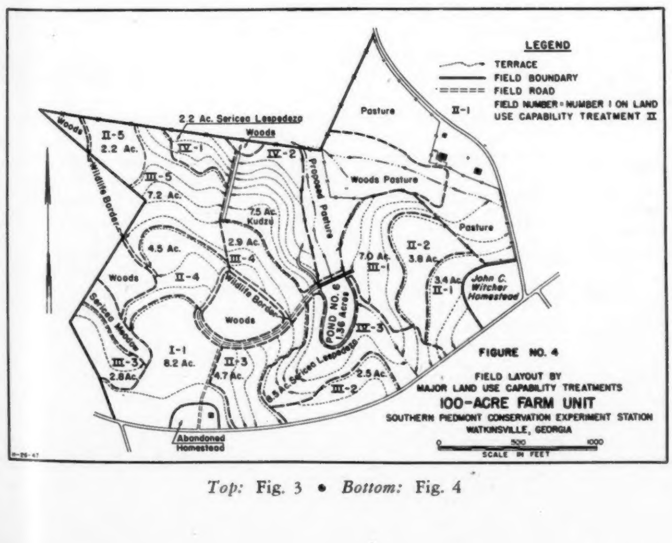
The sericea lespedeza in the center portion of field IV-3 was planted on class III land to connect with the two terrace outlets.

This arrangement of crops concentrated row crops on the lesser slopes and increased the protective crops on land that was more rolling. All row crops followed dead legume residue. Land preparation thus was possible in the winter and spring during short dry spells. The work of planting winter legumes during the rush fall season and the spring delay accompanying turning under green manure crops were eliminated. One possible disadvantage was the loss of nitrates by leaching during the winter.

The sericea was increased to 12.5 acres, including 0.6 acre that was first planted to kudzu. Rotation cropland was reduced to 49.1 acres in this second rotation system adopted. The three rotations on land classes I, II, and III divided equally the acreage in row crops and in the small grain-Kobe lespedeza.

The class II land fields II-1, II-2 and II-5, with 9.4 acres, made one unit and II-3 and II-4, with 9.2 acres, made the other unit for the 2-yr rotation. The three crops of the 3-yr rotation occupied nearly equal acreages each year on fields





Top: Fig. 3 • *Bottom:* Fig. 4

TABLE 1 - ACRES HARVESTED IN EACH CROP BY YEARS ON THE 100-ACRE FARM UNIT

CROP	ACRES HARVESTED					
	1941	1942	1943	1944	1945	1946
Cotton	17.0	12.25	12.10	10.4	10.4	8.0
Corn	10.4	12.90	9.75	12.3	14.2	13.4
Oats	12.0	7.30	7.20	7.2	11.7	11.7
Wheat	16.0	15.30	12.90	7.0	12.9	10.9
Barley	—	—	7.00	9.2	—	—
Annual lespedeza seed	12.0	21.50	10.50	10.4	10.0	6.2
Sericea lespedeza seed	1.7	2.75	4.00	10.2	10.2	7.5
Hay, Kobe, Sericea, etc.	6.1	8.00	9.70	19.4	16.8	17.2
Crimson clover seed	2.6	4.50	—	—	—	—
Peanuts	—	1.33	—	—	—	—
Vetch seed	—	—	—	2.5	—	—
Kudzu	8.1	8.10	7.50	7.5	7.5	10.5
TOTAL CROPLAND	69.0	69.0	69.0	69.0	69.0	69.0

III-1 as one unit, III-2, III-3, and III-4 as another unit, and III-5 as the third unit.

The crops in these rotations provided considerable livestock feed. Therefore in 1943, when sufficient feed had been produced, livestock were added to the farm enterprise to utilize the feed on the farm for greater income. The basic plan of operation continued to be a conservation cropping plan for the fields on the farm.

Mule-drawn equipment was used in so far as was possible for producing these crops. The crop sequence whereby row crops followed dead lespedeza and crotalaria residues allowed ample time for land preparation and planting the summer row crops each spring. These residues contributed to erosion control so that dry spells during the winter were utilized for the land-turning operation. Cultivating the row crops likewise was easily accomplished with the mules. Since both cotton and corn were hand-harvested, the mule-drawn equipment was sufficient for these operations.

Only a portion of the small grain could be planted with the mule equipment each fall. The short time available between row crop and lespedeza harvests and the beginning of winter rains made the grain planting a rush job. Frequently the soil was dry and hard to work. Therefore, the small grain planting with mules was usually limited to that portion furrow-planted between cotton rows without prior tillage. Tractor hire from off the farm was usually resorted to for the small grain planted after the corn and the first year lespedeza.

All the small grain and sericea lespedeza seed harvest was done with hired combines. The mule-drawn mower and attached seed harvester was used for the annual lespedeza seed harvested.

The mule-drawn equipment was also used for all hay harvesting. Likewise weeds and grain stubble were clipped in the annual lespedeza. Weeds were mowed two or more times in the pasture with the mules. These jobs of weed and stubble mowing, however, were severe tasks for the mules. The weather was invariably hot and the work hard. This contributed materially to the poor condition of mules by the end of summer and caused them to be extremely laggard in the fall work.

Development of needed additional pasture areas below the farm pond (Fig. 4) was never accomplished because either the team of mules had to be rested between jobs of field work, or there was not sufficient time between field jobs. Therefore, the livestock phase of the farm program lacked full development because of the limitations of horsepower available.

The acres of the crops harvested each year from 1941 through 1946 are given in Table 1. Cotton occupied 17.0 acres in 1941 and 8.0 acres

TABLE 2 - CROP YIELD BY YEARS ON THE 100-ACRE FARM UNIT

CROP	YIELD					
	1941	1942	1943	1944	1945	1946
Cotton-Lint Pounds	5,636	6,125	4,789	4,369	3,675	3,057
Cotton-Seed Pounds	8,554	8,991	7,556	5,576	5,058	4,243
Corn - Bushel	405	212	270	240	310	400
Oats - Bushel	200	165	144	234	551	448
Wheat-Bushel	144	110	174	98	226	165
Barley - Bushel	—	—	118	102	—	—
Annual Lespedeza Seed - Lbs.	536	3,225	2,124	2,155	1,700	1,025
Sericea Lespedeza Seed-Lbs.	550	830	600	1,233	2,795	2,200
Hay - Tons	7.5	7.1	8.1	15.7	16.1	16.1
Crimson Clover Seed-Pounds	122	476	—	—	—	—
Peanuts - Pounds	—	895	—	—	—	—
Vetch Seed - Pounds	—	—	—	714	—	—

in 1946. Corn acreage was increased a little as the conservation plan was fully developed. Small grain occupied 28.0 acres in 1941 and 22.6 acres in 1946. This reduction in acreage of small grain was caused by the increased acreage of sericea lespedeza. Hay harvested increased from 6.1 acres in 1941 to 17.2 acres in 1946. The 6.1 acres of hay was nearly all cowpeas in 1941. The 17.2 acres in 1946 was from Kobe and sericea lespedeza.

The quantity of each crop harvested by years is shown in Table 2. The maximum amount of lint cotton was produced in 1942 and was 6,125 lb from 12.25 acres, with a per acre yield of 500 lb. Rainfall variations from year to year affected the per acre yields of the cotton, corn and lespedeza. The cotton always followed lespedeza in the rotations used, even the first year of operation.

The 1941 and 1942 wheat crops were planted on portions of the farm that had not been built up from the depleted state found on the Station as a whole when it was secured from the former private owners in 1937. Therefore, low wheat yields of 9.0 and 7.2 bu per acre in 1941 and 1942 reflect the original condition of the land. Wheat yields beginning in 1943 showed considerable improvement and averaged 17.5 bu per acre in 1945. This increase reflects the influence of fertility built up with lespedeza rotations.

Sericea lespedeza seed was harvested in 1941 and 1942 from small areas of fertile soil used as terrace outlets in natural draws through the fields. Therefore, the yield was above 300 lb per acre. When seed was harvested from the poor class III and IV land plantings, the yield was not so high. Repeated annual fertilizer applications of 40 lb of P_2O_5 and 30 lb of K_2O per acre to this sericea gave improved growth and larger yields in 1945 and 1946. The seed yields of 274 and 294 lb per acre in 1945 and 1946, respectively, are more striking when it is realized that the sericea was grazed by dairy cows throughout the spring and summer.

The best corn yield was in 1941, the first year, when corn was planted on class I land previously in crimson clover, and when rainfall distribution was almost ideal for corn production. The poorest corn crop was in 1942 when a summer drought seriously reduced production. This corn also followed crimson clover green manure on class III land.

The increased production of conservation-type crops was accompanied by more livestock on the farm to utilize these crops. The first use of livestock beyond the farm needs was with a small flock of 100 hens and a few head of beef cattle in 1943. The flock of hens was maintained at about that size through 1946.

In 1944 there was organized throughout the county a milk route for sending manufacturing grade milk to the University of Georgia creamery in Athens, 8 miles away. The beef cattle were replaced with grade Jerseys and the sale of milk begun with 4 cows in September of that year. This herd was increased to 8 cows in milk and 3 heifers on hand at the end of 1946. Therefore, as the conservation farm plan was put into effect, an increasing portion of the crops were consumed by livestock on the farm and more of the farm income was from the sale of livestock and livestock products.

The small grains in the crop rotations were used for supplemental grazing by the cattle through the winter months and then for grain harvest. The sericea lespedeza provided heavy grazing during April and May before grass came into production in the permanent pasture. It was also grazed intermittently throughout the summer when dry spells reduced the growth of the grass, and then harvested for seed.

The kudzu was used for supplemental grazing during extreme dry spells in the summer and in late fall. The Kobe lespedeza was used for hay as needed and the remainder harvested for seed. It was not needed for grazing, but was available if droughts had caused the other crops to be used up by the cattle.

The value of all crops produced, regardless of what disposition was made of those crops, was computed for the 6 yr of record, using uniform prices throughout these years. The prices used were: cotton, 17.76c per lb; corn, 75c per bu; oats, 55c per bu; wheat, $1 per bu; barley, 75c per bu; lespedeza seed, 10c per lb; sericea seed, 15c per lb, and hay, $20 per ton. These were the average prices received by farmers in Georgia in 1941[2]. Applying these prices to the total production each year gave crop production values of $2,062, $2,340, $2,040, $2,172, $2,447, and $2,111 for the respective years of 1941 through 1946. Although there was considerable reduction in the acreage of cotton and an increase in hay as the conservation farm plan was more fully put into effect, there was little change in the value of total crops produced.

These values of crops produced do not represent the sale of crops off the farm. Nor do they reflect price changes that actually existed during the 1941-46 period.

The actual gross income, costs, farm income, and inventory on the farm are given by years in Table 3.

The gross income in 1941 and 1942 was based on the sale price of the total crop production, whereas the 1943-46 gross income was based on actual sales and net increase in inventory.

The inventory value of buildings, machinery, and mules reflect permanent improvements to the buildings and depreciation of all three based on the original cost without fluctuation due to wartime inflation. The gross income, costs, and inventory value of feeds do, however, reflect the fluctuation in prices during the period of record.

Therefore, the steady increase in farm income from $1,015.72 in 1941 to $2,560.33 in 1946 was due in part to the change in the price situation over these years and in part to the progress resulting from the change in the farm plan toward more conservation.

Comparative returns from the farm program in 1941 when crops provided all the income and in 1946 when income was from crops and livestock are given in Table 4. The prices used for the crops in both 1941 and 1946 were the average prices received by Georgia farmers in 1941. The prices applying to the livestock items in 1946 are also based on 1941 average prices.

In 1941 the total income was from the crops grown. The total crop production value was $2,062.30. Of this, $491.47

[2]By correspondence with the Georgia Agricultural Extension Service.

TABLE 3 - RECORD OF ACTUAL GROSS INCOME, COSTS, AND INVENTORY VALUES BY YEARS ON THE 100-ACRE FARM UNIT

YEAR	GROSS INCOME	COSTS	FARM INCOME	INVENTORY			
				LAND AND BUILDINGS	MACHINERY	MULES AND LIVESTOCK	FEED
1941	$1,951.62*	$ 935 90	$1,015 72	$4,600 00	$1,123 54	$ 350.00	$NO RECORD*
1942	2,561 06*	964 14	1,596.92	4,500 00	939.32	350.00	NO RECORD*
1943	3,034.82	1,649 03	1,385 89	4,614 14	751 76	1,127.62	818 90
1944	3,329.25	1,594 38	1,734 87	4,705.85	681 93	781.75	1,364 32
1945	4,263 19	2,366 39	1,897.30	4,541 23	675.00	988.00	1,549 36
1946	5,018.22	2,457 89	2,560 33	4,473 27	523.36	947.25	1,510 50

*Note: The gross income in 1941 and 1942 included the total crop production and left no margin for inventory of feed.

TABLE 4 COMPARATIVE RETURNS FROM CROPS ONLY IN 1941 AND CROPS PLUS LIVESTOCK IN 1946 WITH ALL COMMODITIES PRICED ON THE UNIFORM BASE OF AVERAGE PRICES RECEIVED IN 1941

Item			1941	1946
1 Value of crops produced			$2062.30	$2110.65
2 Amount of crops required for maintenance of farm			491.47	544.31
3 Amount available for sale (1—2)			1570.83	1566.34
4 Amount actually sold or on increase in inventory			1570.83	1125.69
5 Amount used by extra livestock on the farm				440.65
6 Returns from extra livestock				1774.83
7 Crop plus livestock returns (4+5+6)			1570.83	3341.17
8 Crops used by extra livestock				440.65
9 Items purchased for extra livestock				826.68
10 Crop production expenses			676.06	790.00
	1941	1946		
Fertilizer	$299.52	$440.00		
Machinery hire	141.10	263.55		
Ginning	45.00	36.45		
Other	90.44	50.00		
Hired labor (picking cotton)	100.00			
11 Livestock and garden products consumed on farm (estimated)			426.00	465.45
12 Farm income (7+11) — (8+9+10)			1320.77	1749.29

was needed for the mules and the family livestock on the farm, leaving $1570.83 for sale. Crop production expenses were $676.06, including $100 worth of hired labor from off the farm for picking cotton. Livestock and garden products consumed on the farm, which were not included in the value of crops produced, amounted to $426.00. The farm income was $1,320.77.

The 1946 value of crops produced, based on average 1941 prices, was $2,110.65, which was practically the same as 1941 even though the cotton acreage was reduced from 17.0 to 8.0. The amount of the crops needed for seed, mule feed, cow feed, for the family needs, etc., to maintain the farm was $544.31, leaving $1,566.34 for sale. Of this amount, only $1,125.69 was sold or retained on inventory, while $440.65 was consumed by the cows and chickens for the sale of livestock products.

The gross crop plus livestock returns to the farm were $3,341.17 in 1946, which was a 113 per cent increase over the income from crops alone in 1941. The livestock expenses were $440.65 for crops on the farm and $826.68 for items purchased off the farm. Crop production expenses were $790.00. Livestock and garden products produced and consumed on the farm, and not included in the value of crops produced, were $465.45. The farm income in 1946 was, therefore, $1,749.29. This was an increase of $428.52, or 32.5 per cent, over the 1941 farm income.

As previously stated, these data are based on the average prices of crops in 1941. They do not show the actual receipts and costs in 1946.

Total actual crop sales in 1946 were $2,152.20, or 42.9 per cent of the total income. Of this amount, $1,186.07 was from lint cotton and $191.78 from cotton seed, or 64 per cent of the crop sales being from the cotton crop. Kobe and sericea lespedeza seed sales provided $563.18, or 26 per cent of the total crop sales. Wheat and corn sales amounted to 10 per cent of the total from crops.

The sale of milk was the single largest source of income with $2,120.39 (including $272.25 subsidy). Other income brought the total sales from the cattle to $2,415.94, or 48.1 per cent of the total income.

The sale of 500 dozen eggs, together with hens and fryers, brought $333.98 income.

Total income from all sources was $5,018.22 for the year.

Crop expenses included $507.96 for all fertilizer used on the farm, $326.22 for machinery hire and ginning, $32.50 for alfalfa seed, and $24.15 for other miscellaneous items, with the total amounting to $890.83. This was 36.3 per cent of all costs.

The cattle expenses included $223.11 for hauling milk, $125.00 for one cow and calf bought, $165.70 for feed bought and other items that make the total $568.64, or 23.1 per cent of the total expenses. The $165.70 for feed included $157.50 for cottonseed meal, $6.35 for salt, and $1.85 for calf feed. The cottonseed meal was actually purchased at the gin in exchange for the cottonseed.

Expenses for the chickens included $485.87 for mixed feed bought off the farm and other miscellaneous costs for a total of $515.32, or 21.0 per cent of the total costs.

Other expenses such as three pigs bought for $26.00, building and machinery repairs for $57.22, taxes, $38.00, etc., brought the total for all items of $2,457.89.

The income less expenses ($5,018.22—$2,457.89) gave a farm income of $2,560.33 for the year. Interest on the inventory of feed, seed, livestock, and machinery at 5 per cent and on the land and buildings at 3½ per cent reduced the farm income from $2,560.33 to a labor income of $2,254.71.

None of the foregoing discussion concerning the actual income and expenses in 1946 takes into consideration the foodstuffs consumed by the farm family. Garden vegetables, corn for roasting ears and meal, wheat for flour, milk, butter, eggs, chickens, hogs, and other items were eaten by the farm operator's family as needed.

It is interesting to note that the $2,415.94 income from the cattle more than paid the $2,128.96 actual cash expenses (not including the $97.06 depreciation on buildings and $231.87 decrease in inventory items of expenses). This $2,415.94 income was received throughout the year with most of it as weekly milk checks, making it possible to meet the operating expenses as they arose. Crop sales then provided the margin of profit. This is a major improvement over the economic situation of many farmers in the Southeast who depend on one or two cash crops for all their income.

SUMMARY

A farm unit of 100 acres was begun in 1941 on the Southern Piedmont Conservation Experiment Station and operated by the tenant to test under actual farm conditions conservation practices developed on the Station.

Cropping practices were employed on the land to give erosion control, soil improvement, and adequate farm income. Row crops were concentrated on the lesser slopes and the protective crops increased on the steeper land.

Two mules were sufficient power for producing 25 acres of row crops and 25 acres of Kobe lespedeza, but could not satisfactorily produce the 25 acres of small grain in rotation with the row crops. Needed pasture development could not be done with the two mules. Kudzu (7.5 acres) and sericea lespedeza (12.5 acres) were successfully planted with the mules.

As the conservation plan was developed through the years, 1941 to 1946, the cotton was reduced from 17 to 8 acres and hay increased from 6 to 17 acres. Nevertheless the total value of crops produced based on uniform prices, remained practically constant during this period.

The full development of the cropping system made possible the use of dairy cattle in the farm plan for greater income.

The small grain in rotation cropland, crimson clover in the permanent sod pasture, and the sericea and kudzu on the steeper and more severely eroded areas supplemented the grass pasture to give nearly year-round grazing for the cattle.

Comparative records of income and costs, based on uniform prices, showed that in 1941, from crop production alone, the farm income was $1,320.77 and in 1946 from crops and livestock it was $1,749.29.

The sales of livestock and livestock products, when the full conservation and livestock programs were in effect, were distributed throughout each week of the year and amounted to more than the total farm operating expenses. The sale of surplus crops provided the margin of profit.

Analytical Procedures for Determining the Effect of Land Use on Surface Runoff

By W. D. Potter

THE Central Great Plains Experimental Watershed located near Hastings, Nebraska, is one of the research projects of the Soil Conservation Service*. W-III and W-V are two watersheds included in this project on which measurements of rainfall and surface runoff have been made for the period 1939-46. Watershed W-III has an area of 481 acres, 15 per cent of which has been kept in pasture, 2 per cent in meadow, 80 per cent in cultivation, and 3 per cent in other uses. Watershed W-V has an area of 411 acres, 11 per cent of which has been kept in pasture, 9 per cent in meadow, 77 per cent in cultivation, and 3 per cent in other uses. The crops and tillage practices for both watersheds were essentially the same for the period of record[1]†. It is now planned to change the land use for one of the watersheds while the land use for the other is kept unchanged. It is the purpose of this paper to outline analytical procedures designed to measure the effect of this proposed change in land use upon the rates and amounts of surface runoff.

The first section of the paper deals with procedures for testing the normalcy of the rainfall experienced during the period of record and the second section with the analysis of the surface runoff.

NORMALCY TESTS FOR RAINFALL

Although rainfall is only one of the many factors that affect surface runoff, it is one of the important factors. Man may control such cultural practices as crops and tillage; he may minimize the effect of physiographical differences by the careful selection of comparable watersheds, but he has no control over the rainfall that may be experienced during the life of an experiment. The first step in the analysis of any hydrologic data should be to compare the rainfall experienced during the period of record with that experienced over a long period of years. In other words, the rainfall experienced during the period of record should be tested to determine how good a sample it is of the normal rainfall defined by long-time records. For the Hastings data this test was applied only to the intensities and amounts of rainfall.

Rainfall intensities may usually be tested as to the number of excessive storms and as to the magnitude of intensities that may be expected for various recurrence intervals.

Excessive Storms. The following tabulation shows the number of excessive storms for the period of record as compared with Yarnell's 30-yr average[2].

TABLE 1. NUMBER OF EXCESSIVE STORMS

Station B38R (Meteorological Station) Hastings, Nebraska

Year	'39	'40	'41	'42	'43	'44	45	'46	Total	Average	Yarnell's 30-year average
6 months (Apr.-Oct.)	6	2	4	8	8	6	5	2	41	5.1	5.3
Calendar year	6	2	5	8	9	6	5	2	43	5.4	5.6

Of the 43 excessive storms that occurred during the period of record, 41 storms occurred during the 6-mo period of April to October. The average for this 6-mo period agrees very closely with Yarnell's 30-yr average, as does the average number per calendar year. From this comparison it may be assumed that, in so far as the number of excessive storms are concerned, the period of record is a normal sample.

Magnitude of Intensities for Various Recurrence Intervals. The magnitude and frequency of rainfall intensities were tested by comparing the maximum record intensities for 15, 30, and 60 min with those obtained by Yarnell from long-time rainfall records. The maximum 15-min intensity for each year was tabulated in a descending order of magnitude. Plotting positions were calculated from the formula: $F=(2N-2M+1)/(2M-1)$, in which F = the plotting position, N = length of record in years, and M = order number of item (highest = 1, next = 2, etc.)[3]. The intensities versus frequencies of occurrence were plotted on log-log graph paper with intensities as ordinates and frequencies of occurrence (calculated plotting positions) as abscissas. An average curve for the plotted points was then calculated by least squares. The plotting position for frequencies of occurrence of once in 2 yr; once in 5, 10, 25, and 50 yr, was determined by assuming a 50-yr record and solving for F in the above formula. Yarnell's values of 15-min intensities for these frequencies were then plotted on the graph and an average curve drawn through the points. Since the Yarnell values plotted so nearly in a straight line, the average curve was not calculated but was fitted by eye. This same procedure was followed in comparing maximum 30 and 60-min intensities. A summary of these comparisons is given in Table 2.

TABLE 2. RAINFALL INTENSITIES (INCHES PER HOUR)

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
15-min intervals					
Record intensities	3.00	3.78	4.30	5.20	6.20
Yarnell intensities	3.65	4.40	5.00	5.75	6.70
30-min intervals					
Record intensities	1.95	2.47	2.85	3.48	4.20
Yarnell intensities	2.43	3.05	3.58	4.25	5.10
60-min intervals					
Record intensities	1.25	1.48	1.65	1.90	2.18
Yarnell intensities	1.60	1.95	2.23	2.60	3.05

Table 2 indicates that the magnitude of rainfall intensities for the period of record was below the normal defined by long-time U.S. Weather Bureau records. This fact would have to be taken into account in any analyses of runoff records for that period. For example, suppose that peak rates of runoff for a 25-yr recurrence interval had been determined from an analysis of the runoff records. These peak rates would have had to be increased so that they would be comparable with the peaks that would have resulted if the rainfall intensities had been normal. In the analysis of runoff, presented later in this paper, the purpose is to compare the differences in runoff between two watersheds during the 8-yr period (1939-46) with the differences between the same watersheds for some future period. During this second period, the land use for one of the watersheds will have been changed. To determine the differences in runoff that might be expected over a long period of years as a result of this change in land use, it is planned to make a similar analysis of rainfall intensities for the second period. The runoff differences between the two watersheds for both periods will then be adjusted to conform with the normal rainfall intensities and the changes in runoff calculated from these adjusted values.

Before passing on to the next step in the analysis of rainfall data, a word of caution should be inserted concerning the use of Yarnell's rainfall intensity values[2]. These values were derived from data obtained from a tipping-bucket type of raingage and tabulations of the amount of rainfall were made at 5-min intervals. True maximum intensities can be obtained from such tabulations only when the changes in intensities occur at the beginning or end of a 5-min interval. When

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Soil and Water Division.

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*All work on this project is done in cooperation with the Nebraska Agricultural Experiment Station.

†Superscript numbers refer to appended references.

the maximum intensities begin or end near the middle of a 5-min interval, the calculated maximum intensity will be less than the actual intensity. For this reason, Yarnell's values should be increased approximately 8 per cent for 15-min intensities, 7 per cent for 30-min intensities, and 4 per cent for 60-min intensities.

In drawing the lines of equal amounts of rainfall for various periods of time, Yarnell probably ignored minor weather irregularities that his data showed to be local in areal extent. Another source of possible error occurs in the interpolation between any two isohyetals. In making such an interpolation, the assumption must be made that the rate of change in rainfall amounts between the isohyetals is constant. This assumption is not necessarily true. For these reasons, it is advisable to check Yarnell's values with the records from the nearest first order Weather Bureau stations in determining normal intensities for any locality.

It is, therefore, planned to check Yarnell's values of rainfall intensities for Hastings with records from the Weather Bureau stations at Lincoln and North Platte, Nebraska, and Concordia, Kansas. Because of this pending check, Yarnell's values given in Table 2 were not increased by the recommended percentages*.

Amounts of Rainfall. A procedure similar to that described for rainfall intensities was used to test the normalcy of the rainfall amounts during the period of record. Since 96 per cent of the total number of excessive storms, as well as 83 per cent of the total rainfall and 91 per cent of the total runoff for the period of record occurred during the 6-mo growing season from April to October, the rainfall for this period rather than the annual rainfall was used in this test. Amounts of rainfall for this 6-mo period were tabulated for each year of record. Frequencies were determined from the formula, $F=(2N-2M+1)/(2M-1)$, the amounts of rainfall versus frequencies plotted on log-log graph paper, and a least squares curve computed[5]. A similar curve was then computed from the records of the Weather Bureau station at Hastings for the 43-yr period, 1895 to 1937. A comparison of the amounts of rainfall obtained from the two curves for various recurrence intervals is shown in Table 3.

TABLE 3. AMOUNTS OF RAINFALL FOR 6-MONTH PERIOD (APRIL-OCTOBER) IN INCHES

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
Period of record (1939-46)	17	24	29	38	49
Weather Bureau records (1895-37)	18	24	28	34	41

It is doubtful if a probability curve computed from only 8 yr of record can be extrapolated with a reasonable degree of accuracy beyond the 25-yr recurrence interval. Within this limitation the values derived from the two curves agree very closely, and it may be assumed that the amounts of rainfall experienced during the period of record were normal.

Summarizing the results of the rainfall tests, we find that the number of excessive storms and the amounts of rainfall for the period of record compared favorably with the normal as defined by long-time Weather Bureau records. The maximum rainfall intensities were found to be below normal although the final decision will be held in abeyance pending a check of the Yarnell values.

ANALYSIS OF SURFACE RUNOFF

As stated previously, the purpose of this report is to outline analytical procedure for determining the effect of a change in land use on rates and amounts of surface runoff. The effect of this changed land use can be measured if relationships between the peak rates of the two watersheds and between their total runoffs can be determined for the initial period and compared with similar relationships for the final period. The differences between the initial and final relationships would then be a measure of the effect of the changed land use, provided that the rainfall experience for the two periods had been similar.

*Since this paper was written, probability curves were computed from the 20-year rainfall record at Lincoln, and the intensities were found to agree very closely with those obtained from the Hastings records.

Three plans were considered for obtaining the relationships between the peak rates of runoff from the two watersheds.

Peak Rates Versus Rainfall Intensities. The first of these plans was to determine the relationship between rainfall intensities and peak rates for each watershed. With such a relationship established, it would then be possible to compare peak rates from the two watersheds for all values of rainfall intensity.

The success of such a plan would depend upon the truth of the assumption that rainfall intensity is the principal factor affecting peak rates of runoff. The analysis of runoff data from small watersheds located in many parts of the country has proven the fallacy of this assumption. Although it is true that rainfall intensity is one of the factors affecting surface runoff, it has been shown to be only one of the many factors and not necessarily the dominant one. In the light of these facts, it was evident that the relationship between rainfall intensities and peak rates of runoff could only be determined if the effect of all other factors could be kept constant. Since it obviously was not feasible to attempt to control all these other factors, this method for determining peak rate comparisons between the two watersheds was abandoned.

Direct Comparison of Peak Rates. The second plan that was considered was to make a direct comparison of the peak rates from the two watersheds for each storm during the period of record. The peak rates from one watershed would be plotted against the corresponding peak rates from the other watershed and an average curve would then be computed.

Although the watersheds are approximately only a mile and a half apart, an examination of the rainfall showed that for any individual storm both the rainfall intensities and the amount of rainfall varied considerably between the two watersheds. A method of correcting for these differences in rainfall was used by Baird in his analysis of the peak rates of runoff from two watersheds of the Blacklands Experimental Watershed[4]. Briefly, this method consists of tabulating for each watershed and for each storm the difference between the maximum rainfall intensity for the estimated time of concentration and the peak rate of runoff. These values for one watershed are then plotted against the corresponding values for the other watershed and a straight line (computed by least squares) drawn amongst the points. In the equation of this line, $y=ax+b$, $(P-r)$ is substituted for y and (P_1-r_1) substituted for x, P and P_1 being the rainfall intensities and r and r_1 the peak rates of runoff for the two watersheds. The rainfall intensities P and P_1 are then assumed to be equal and the equation is solved for the peak rate of runoff from one watershed in terms of the peak rate and the rainfall intensity for the other watershed. Using this modified equation and the record peak rates and rainfall intensities for one watershed, corresponding values of peak rates are computed for the other. The record peak rates from the one watershed are then plotted against the corresponding computed peak rates for the other watershed, and the relationship is expressed by a straight line computed by least squares. This same procedure could be followed for the second period during which the land use for one of the watersheds had been changed. The difference in the peak rate relationships for the two periods would be taken as a measure of the effect of the changed land use. (The limitations of this method for determining the effect of land use on surface runoff are discussed later in this report.)

It is planned to apply the above procedure to the Hastings data as soon as a complete tabulation of rainfall intensities and peak rates of runoff are completed.

Probability Curves. The third plan that was considered as a means for determining the effect of land use on the peak rates of surface runoff was to plot the peak rates for the first comparative period against their probable frequency of occurrence. This would be done for the peak rates from each of the two watersheds and average curves computed for the plotted points. The relationship between the peak rates of the two watersheds would then be determined by plotting the peak rates (curve values) for various frequencies for one watershed against the corresponding peak rates (for the same frequencies) for the other watershed. This procedure would be repeated for the second comparative period and the difference

in peak rate relationships taken as a measure of the changed land use.

In general, probability curves fall into one of two classes. In one, only the highest peak rate per unit of time is considered. The probable frequency of occurrence is computed in terms of the average number of time units that might be expected to elapse before a given peak rate would be equalled or exceeded. Thus a frequency of occurrence of once in 5 yr would mean that a designated peak rate could be expected to be equalled or exceeded on an average of one year in 5 yr. During that one year, however, the designated value might be equalled or exceeded several times or only once.

The second class of probability curve considers all peak rates above a predetermined base. The probable frequency of occurrence is computed in terms of the average number of times that a given peak rate will be equalled or exceeded in some interval of time. Thus a frequency of five times in 25 yr would mean that a designated peak rate could be expected to be equalled or exceeded on an average of five times in 25 yr. These five times, however, might occur all in one year, or they might be distributed over several years.

Both of these general types of probability curves have their distinct uses in estimating the frequency of flood occurrences. In determining changes in peak-rate relationships between two watersheds during two comparative periods, either or both types should prove useful.

Four generally accepted methods for computing the class one type of probability curves were considered in this paper.

1 *Brandt's Probability Curve*[3]. This probability curve was used in the comparisons of rainfall data and the procedure for computing it has already been explained. A comparison of the peak rates for the two watersheds for various recurrence intervals is shown in Fig. 1, and in Table 4.

TABLE 4. PEAK RATES OF SURFACE RUNOFF (CFS PER ACRE)

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
W-III	0.32	0.68	1.10	2.06	3.80
W-V	0.24	0.69	1.34	3.26	7.67

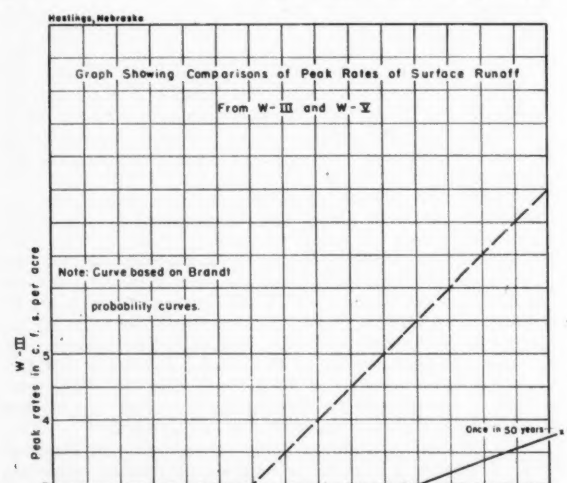


Fig. 1

2 *Gumbel's Probability Curve*[5,6]. Gumbel computed the frequency of occurrence of the highest and lowest of a series of peak rates of runoff as a function of the number of items in the series. The frequency of the intermediate peak rates are then determined by prorating the difference between these two values. The peak rates are plotted against these frequencies on an especially prepared graph paper and an average straight line computed by least squares. Fig. 2 and Table 5 show the peak rates for the Hastings watersheds for various recurrence intervals as computed by this method.

TABLE 5. PEAK RATES OF SURFACE RUNOFF (CFS PER ACRE)

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
W-III	0.41	0.78	1.02	1.34	1.56
W-V	0.38	0.73	0.96	1.26	1.47

3 *Foster's Probability Curve (Pearson's Type I)*[7,8]. Foster tabulated peak rates of runoff in a descending order of magnitude and determined the frequency of occurrence from the formula $F=(M-0.5)/N$, in which M equals the order number of the item and N equals the total number of items. The peak rates are then plotted against the corresponding frequencies on log-probability paper. A skew coefficient is then computed from the series of peak rates and this coefficient is used to correct Pearson's Type I probability curve. This curve, corrected for skew, is then plotted on the same log-probability paper as were the peak rates of runoff. Fig. 3 and Table 6 show the peak rates computed by this method for the two watersheds.

TABLE 6. PEAK RATES OF SURFACE RUNOFF (CFS PER ACRE)

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
W-III	0.29	0.60	0.88	1.26	1.52
W-V	0.35	0.67	0.85	1.06	1.16

4 *Foster's Probability Curve (Pearson's Type III)*[7,8]. The procedure for computing this curve is the same as for the Pearson's Type I curve, except that the skew coefficient is different and is used as a correction for Pearson's Type III prob-

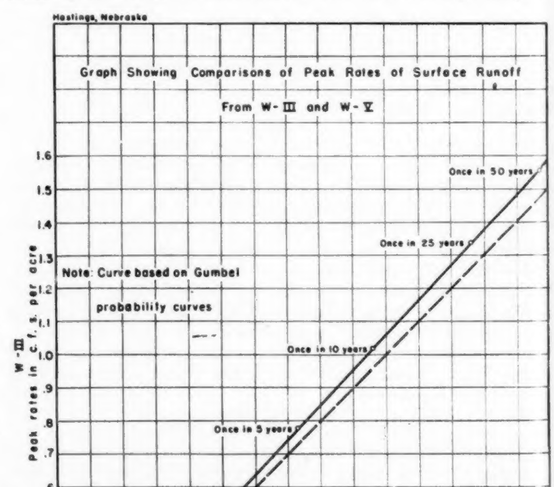


Fig. 2

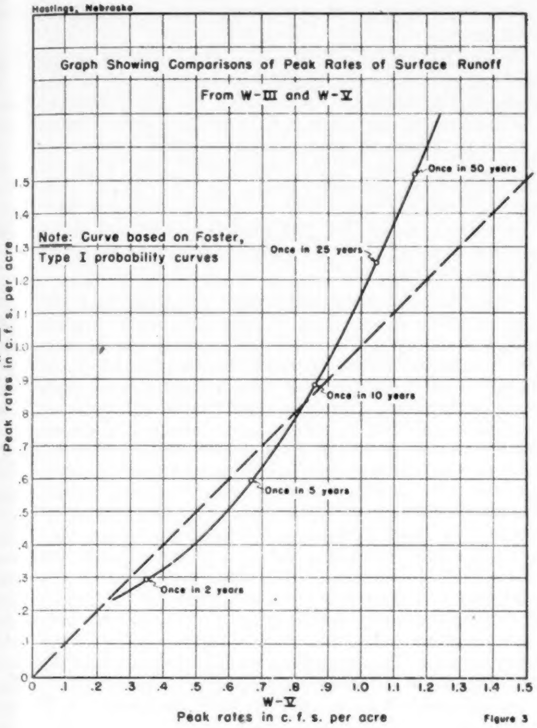


Fig. 3

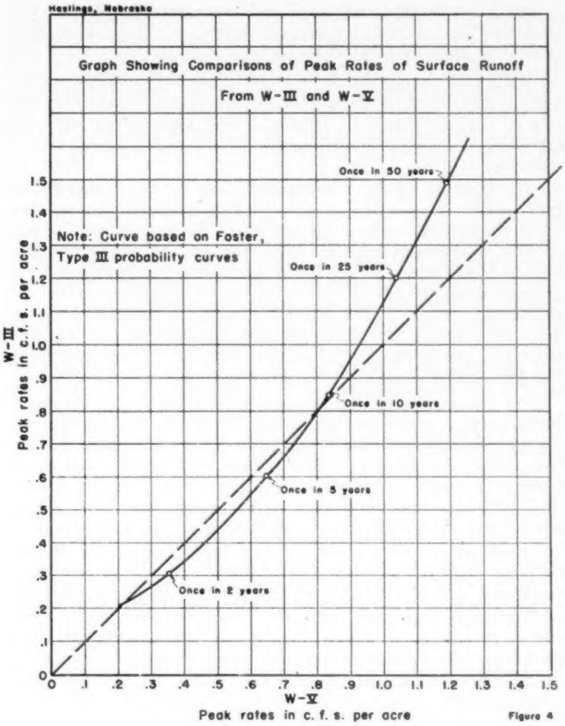


Fig. 4

ability curve. The peak rates of runoff computed by this method are shown in Fig. 4 and in Table 7.

TABLE 7. PEAK RATES OF SURFACE RUNOFF (CFS PER ACRE)

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
W-III	0.31	0.60	0.85	1.20	1.49
W-V	0.35	0.65	0.83	1.04	1.19

Table 8 shows a comparative summary of the peak rates obtained for W-III and W-V from the four probability curves.

TABLE 8. PEAK RATES OF SURFACE RUNOFF (CFS PER ACRE)

Recurrence interval once in	2 yr	5 yr	10 yr	25 yr	50 yr
			Watershed W-III		
Gumbel	0.41	0.78	1.02	1.34	1.56
Foster, Type I	0.29	0.60	0.88	1.26	1.52
Foster, Type III	0.31	0.60	0.85	1.20	1.49
Brandt	0.32	0.68	1.10	2.06	3.80
			Watershed W-V		
Gumbel	0.38	0.73	0.96	1.26	1.47
Foster, Type I	0.35	0.67	0.85	1.06	1.16
Foster, Type III	0.35	0.65	0.83	1.04	1.19
Brandt	0.24	0.69	1.34	3.26	7.67

It will be noted that there is a fairly close agreement between the values obtained from the two Foster-type curves and those from the Gumbel curves. Compared with the Gumbel values the per cent difference for W-III varies from 4 per cent for 50-yr recurrence intervals to approximately 26 per cent for 2-yr intervals and averages 15 per cent. For W-V the per cent difference varies from 8 per cent for 2-yr recurrence intervals to 20 per cent for 50-yr intervals and averages 14 per cent. The values obtained from the Brandt-type curves agree fairly well with those obtained from the other curves within the range of the period of record (0-8 yr) but differ widely for recurrence intervals greater than 10 yr.

It should be remembered that in this analysis we are interested not so much in the numerical value of the peak rates as we are in the change in peak rate relationships that may have taken place during the second comparative period. Peak rates obtained from each of the four probability curves for any recurrence interval could differ widely with each other for both comparative periods. The changes in the peak rate relationships, however, might be very similar regardless of which type of probability curve was used in its determination. A probability curve, therefore, should not be discarded simply because it does not coincide with other curves. The criteria as to which of the curves should be selected and the weight to be given to those selected should be twofold. First, how closely does the curve fit the plotted points? Secondly, does the curve express a relationship which seems reasonable, in the light of what is known about the phenomenon being studied?

Statistics provide us with the procedure for making the first test, the calculation of the standard error of estimate. The standard error of estimate defines the limits of deviation from the curve that may be expected for approximately two-thirds of the plotted points. To calculate the standard error, the difference between the theoretical or curve value and the actual value is tabulated for all plotted points. The sum of the squares of these differences is then divided by the number of items to obtain the average. The square root of this average is the standard error of estimate.

The standard error of estimate was computed for each of the four types of probability curves as shown in Table 9.

TABLE 9. STANDARD ERRORS OF ESTIMATE (CFS PER ACRE)

Type of probability curve	Brandt	Gumbel	Foster I	Foster III
W-III	0.12	0.10	0.09	0.09
W-V	0.36	0.10	0.11	0.11

It will be noted that the standard error for the Brandt-type curve for W-V is more than three and one-half times that for the other curves. This would indicate that this type curve is not suited for the distribution of peak rates presented by the W-V data and, therefore, should not be considered in any determination of changes in peak rates between the com-

parative periods. The standard errors for the other three types of curves are small and approximately equal so that all three can be considered to have passed the first test.

Before applying the second test it would be well to consider briefly some of the physiographic factors that affect the rate of surface runoff to determine how their effect might be expected to vary with different rainfall and antecedent soil moisture.

Permeability of the soil, its depth and porosity, and drainage density are three important physiographic factors that affect the rate of surface runoff. Until the time when the soil on two watersheds becomes saturated, the watershed having soils of lower permeability could be expected to have the higher peak rates of runoff, the difference being a constant approximately equal to the difference in the infiltration rates of the soils. When the soils of both watersheds had become saturated the difference in permeability would no longer be effective and the peak rates would approach equality.

For storms during which the soil of neither of two watersheds became saturated, differences in depth and porosity of the soils would not affect the peak rates of surface runoff. For storms during which the shallow soil of one watershed became saturated but not the deep soil of the other, the watershed with the shallow soil could be expected to have higher peak rates. The difference would be approximately equal to the infiltration rate of the non-saturated soils. For storms during which the soils of both watersheds became saturated, the peak rates could again be expected to approach equality.

Watersheds having the most efficient collecting system, that is, the largest drainage density, could be expected to have the highest peak rates of surface runoff up to the time when the runoff exceeded the channel capacities. During flood periods, however, the capacity of the principal drainage ways could be expected to be exceeded and the effect of the more rapid collecting system in increasing peak rates would be minimized. Peak rates would approach a constant difference equal to the difference in the capacity of the principal drainage channels.

An examination of Figs. 1, 2, 3, and 4, shows that the two Foster-type probability curves give values that would indicate that the peaks from W-III could be expected to exceed those from W-V by increasingly larger percentages. The Brandt-type curves (already discarded because they did not fit the plotted points) indicate that the reverse could be expected. That is, that the peaks from W-V could be expected to exceed those from W-III by even greater percentages. The Gumbel-type curves give values indicating that the peak rates from W-III could be expected to exceed those from W-V by a small constant percentage. These observations are also shown in Table 10, in which the ratio of the peak rates from W-III to those from W-V is tabulated for various recurrence intervals.

TABLE 10. RATIO OF PEAK RATES FROM W-III TO PEAK RATES FROM W-V (PER CENT)

Recurrence interval, yr	Foster (Type I)	Foster (Type III)	Brandt	Gumbel
2	83	89	134	107
5	90	92	98	107
10	104	102	82	107
25	119	116	63	107
50	131	125	50	107

In the light of the preceding discussion concerning the reaction under flood conditions of some of the principal factors that affect the magnitude of peak rates, the relationship indicated by the Gumbel curves would seem to be the most reasonable. Accordingly, the Gumbel curves will be given more weight than the Foster types in comparing the relationships between the peak rates from the two watersheds for the first and second comparative periods.

The four probability curves considered so far have all been of the class one type. That is, only the highest peak rate per year was used in their derivation. It is also planned to compare the peak rates of the two watersheds by computing class two type probability curves for which all the peak rates above a predetermined minimum will be considered. This was not done at this time pending a complete tabulation of the 1946 peak rates.

Amounts of Surface Runoff. The same three plans of analyses that were considered for the peak rate comparisons were also considered in determining the relationship between the amounts of surface runoff from the two watersheds. As previously stated, 96 per cent of the total number of excessive storms, 83 per cent of the total rainfall, and 91 per cent of the total runoff for the period of record occurred during the 6-mo periods beginning with April and ending in September. The surface runoff for this period rather than the annual amount was used in determining the relationships between the two watersheds.

Total Rainfall vs. Total Runoff. The same discrepancies as were observed in the study of peak rates were found to exist between total rainfall for individual storms and the total runoff. For the same total rainfall the amounts of runoff were found to vary widely. This wide variation is no more than could be expected when it is remembered that the amount of rainfall is only one of many factors affecting the amount of surface runoff. A rain of a given amount falling upon nearly saturated soil with sparse vegetal cover would be expected to produce more surface runoff than the same rain falling upon dry soil with a dense vegetal cover.

In some localities it has been found that, if the total rainfall and runoff are considered for a period of months instead of for individual storms, a relationship between them can be established. This would only be true when the combination of factors that determine the amount of runoff have been similar throughout periods for which the rainfall amounts have been the same. For example, it would seem probable that during dry periods of little rainfall the amounts of rain falling upon dry soil would be approximately the same. If the type and pattern of the runoff-producing storms and the kind and density of vegetal cover were also similar, the amounts of runoff would be approximately equal. Similarly for wet periods of equal rainfall it would seem probable that approximately the same amounts of rain would fall upon wet soils. If the other factors were also similar, equal amounts of runoff would result.

A study was made to determine if such a relationship could be established for the Hastings data. Six-month amounts of rainfall for both watersheds were plotted against corresponding amounts of runoff. These values were plotted on semilogarithmic paper and average straight lines computed by least squares. The standard errors of estimate for the two curves were 0.47 in for W-III and 1.35 in for W-V. These standard errors indicated a poor fit for the plotted points, especially for those of W-V. Besides being a poor fit, the curves when extrapolated much beyond the range of the experimental data gave values for runoff that were two or three times the value of the corresponding rainfall.

The next step was to determine if a better fit could be obtained with another type curve. The rainfall and runoff values were replotted on cartesian paper and average curves of the type $y = a + bx + cx^2$ were computed by least squares. The standard errors of estimate for these curves were found to be 0.31 in for W-III and 0.72 in for W-V. Not only were the standard errors much less than the 0.47 in and 1.35 in found for the semilogarithmic curves, but the new curves when extrapolated gave reasonable values. One other statistical test was made, a study of variance to determine if the relationship expressed by the curves could be considered significant. From this study the conclusion was reached that both curves were significant and that the one for W-III was highly significant.

A tabulation was prepared to show the amounts of runoff that might be expected from the two watersheds for various recurrence intervals. Values of rainfall for the recurrence intervals were obtained from the probability curve computed from the 43-yr rainfall record for Hastings. The rainfall versus runoff graphs were then entered with these amounts of rainfall and the corresponding amounts of runoff tabulated. This comparison of runoff is shown in Fig. 5 and in the following tabulation.

TABLE 11. AMOUNTS OF RAINFALL AND SURFACE RUNOFF (INCHES)

Recurrence interval once in	2 yrs	5 yrs	10 yr	25 yr
6-mo rainfall (1895-1937 records)	18	24	28	34
6-mo runoff from W-III	1.79	3.01	4.02	5.84
6-mo runoff from W-V	1.45	2.71	3.80	5.87

Direct Comparison of Amounts of Surface Runoff. As previously stated, it was found that the rainfall for the two watersheds differed in both intensities and amounts for individual storms. This was also found to be true when the rainfall data for 6-mo periods for the two watersheds were compared. It was evident that a relationship between amounts of surface runoff could not be obtained from a direct comparison of these values unless some correction was applied to compensate for the unequal rainfall.

The method used to accomplish this has already been described in the discussion on direct comparisons of peak rates. The differences between the 6-mo rainfall and 6-mo runoff from one watershed were plotted against corresponding values for the other watershed. The relationship was expressed by a straight line computed by least squares. The standard error of estimate was found to be 0.52 in and a study of variance showed the relationship to be highly significant. The equation of the straight line expressing this relationship was $y=0.877x+1.51$, in which y equalled the values of 6-mo rainfall *(P)* minus 6-mo runoff *(R)* for W-III and x equalled corresponding values P_1 minus R_1 for W-V. When $(P-R)$ is substituted for y and (P_1-R_1) substituted for x, the equation becomes $(P-R)=0.877\ (P_1-R_1)+1.51$. If the rainfall had been equal for the two watersheds, P would have equalled P_1 and the equation could have been written $R=0.123\ P_1-0.877\ R_1+1.51$. Using this formula and the record values of rainfall and runoff for W-V, corresponding values of R were computed for W-III. The record values of R_1 (W-V) were then plotted against these computed values of R (W-III). The same procedure was followed in computing values of R_1 corresponding to record values of rainfall and runoff for W-III. The record values of R (W-III) versus the computed values of R_1 (W-V) were also plotted on the graph. The relationship between R and R_1 was expressed as a straight line computed by least squares. The standard error of estimate was found to be 0.56 in and the relationship expressed by a straight line to be highly significant. The comparison of surface runoff from the two watersheds as derived by this method is shown in Fig. 6 and in Table 12.

TABLE 12. AMOUNTS OF SURFACE RUNOFF (INCHES)

6-mo runoff from W-III	1.00	2.00	3.00	4.00	5.00	6.00
6-mo runoff from W-V	0.75	1.50	2.23	2.97	3.70	4.45

For simplicity in the following discussion the procedure just described will be referred to as Plan II. Likewise the procedure in which the comparison of runoffs is made by first establishing relationships between amounts of rainfall and amounts of runoff, will be referred to as Plan I.

Table 13 shows a comparison of the amounts of runoff for W-V obtained by Plans I and II and corresponding to various amounts of runoff for W-III.

TABLE 13. AMOUNTS OF SURFACE RUNOFF (INCHES)

6-mo runoff, W-III	1.00	2.00	3.00	4.00	5.00	6.00
Plan I, 6-mo runoff, W-V	0.75	1.63	2.63	3.80	4.90	6.10
Plan II, 6-mo runoff, W-V	0.75	1.50	2.23	2.97	3.70	4.45

An examination of Table 13 and Figs. 5 and 6 shows that within the range of the experimental data (0 to 3.8 in) both plans give amounts of runoff that are fairly close. Beyond this range, however, the differences become increasingly greater. Statistical tests indicate that there is little to choose between the accuracy that might be expected from the two plans. The standard errors of estimate for the two curves used in Plan I are 0.31 in and 0.72 in as compared with 0.52 in and 0.56 in for the curves used in Plan II. All curves were found to be significant.

Plan II assumes that the relationship between amounts of runoff for the two watersheds can be expressed as a straight line. This could be true only if the factors that affect surface

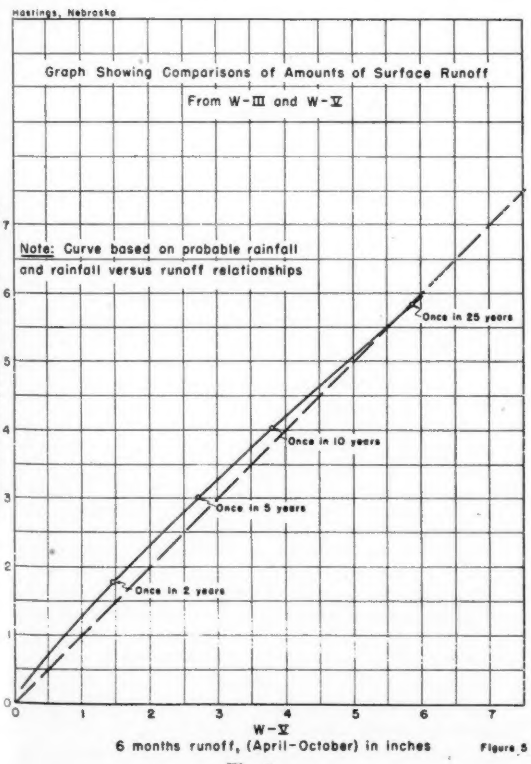


Fig. 5

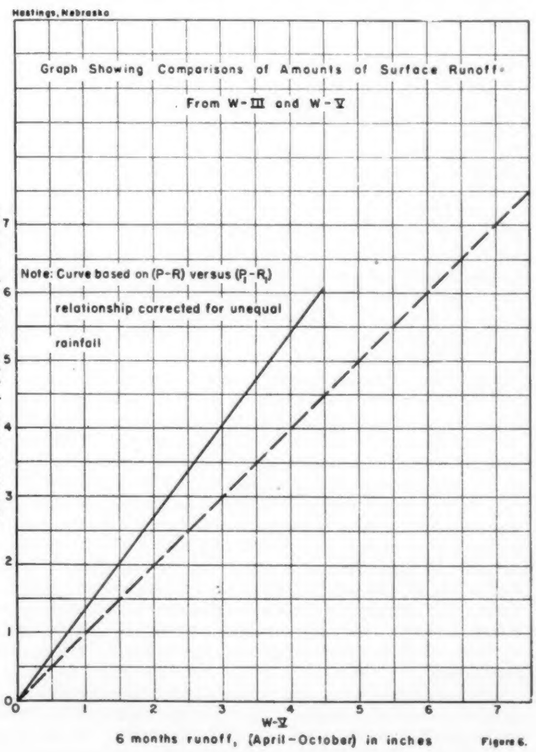


Fig. 6

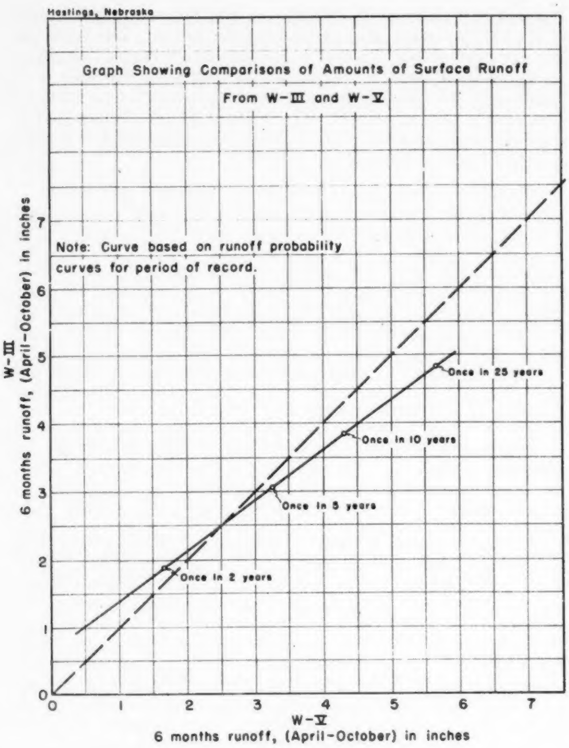


Fig. 7

runoff reacted similarly for the two watersheds for all values of rainfall. It has been shown in the discussion of the reactions of some of these factors that such a similarity is unlikely. A more plausible assumption is that, for periods when the rainfall amounts are small, the differences between the amounts of runoff for two watersheds would be relatively small and due primarily to differences in infiltration opportunity and infiltration rates. If, in addition to lesser infiltration opportunity and infiltration rates, one watershed had shallower soils, then for periods when the rainfall amounts were greater, the runoff differences could be expected to increase. This would be due to the fact that the soils of shallow depth would have become saturated more often during the period than would the deep soils. For periods when the rainfall amounts were excessive, the runoff differences could be expected to approach equality. The soils of both watersheds would then have become saturated approximately the same number of times and the effect of unequal infiltration rates would be minimized.

The relationship derived from Plan I agrees much more closely with what might reasonably be expected than does that derived from Plan II. Plan I shows that, for increasing amounts of rainfall, the differences in runoff amounts increase to a maximum of 0.37 in and then approach 0.00 in as the rainfall amounts are further increased. Plan II, however, shows ever-increasing differences in runoff amounts.

The above discussion illustrates the danger in extending a statistical curve much beyond the range of experimental data without first making a careful analysis of all the factors involved. Within the range of experimental data, a straight line might be the best statistical fit for the plotted points and within this range give fairly accurate values. This does not mean, however, that the straight line would still have been the best fit if a wider range of experimental data had been available.

Probability Curves. In some localities it may not be possible to establish a sufficiently accurate relationship between amounts of rainfall and amounts of runoff. In such cases probability curves may be used to make comparisons of the amounts of runoff from two watersheds.

A Gumbel-type curve was computed for each of the Hastings watersheds. Six-month amounts of runoff for each watershed were then computed from these curves for various recurrence intervals. A comparison of these amounts is shown in Fig. 7 and in Table 14.

TABLE 14. AMOUNTS OF SURFACE RUNOFF (INCHES)

Recurrence intervals once in	2 yr	5 yr	10 yr	25 yr
6-mo runoff from W-III	1.86	3.05	3.83	4.83
6-mo runoff from W-V	1.66	3.26	4.30	5.65

A comparison of these values with those obtained by Plan I is shown in Table 15.

TABLE 15. AMOUNTS OF RAINFALL AND SURFACE RUNOFF (INCHES)

Recurrence intervals once in	2 yr	5 yr	10 yr	25 yr
6-mo rainfall (1895-1937 records)	18	24	28	34
6-mo runoff from W-III				
Plan I	1.79	3.01	4.02	5.85
Probability curve	1.86	3.05	3.83	4.83
6-mo runoff from W-V				
Plan I	1.45	2.71	3.80	5.87
Probability curve	1.66	3.26	4.30	5.65

The values obtained from the probability curves compare fairly closely with those obtained from Plan I. For W-III, the difference varies from one per cent for a recurrence interval of 5 yr to 17 per cent for 25-yr intervals. The average difference is approximately 6 per cent. For W-V, the differences vary from 4 per cent for a recurrence interval of 25 yr to 20 per cent for 5-yr intervals. The average is approximately 13 per cent.

It will be noted that the Plan I values for W-III equal or exceed those for W-V. The probability curves, however, indicate that with the exception of the 2-yr recurrence interval, the reverse is true. This apparent discrepancy is explained when it is remembered that the Plan I values were obtained for equal amounts of rainfall on the two watersheds, whereas the probability curves were computed from the record amounts of runoff resulting from actual rainfall. Table 16 shows that the actual rainfall was not equal for the two watersheds.

TABLE 16. APRIL TO OCTOBER PRECIPITATION IN INCHES

W-III	W-V
26.80	28.02
23.86	25.45
20.25	21.46
19.16	18.87
18.16	18.48
13.84	13.89
12.52	11.19
8.14	7.66

For the two years when the rainfall was between 18 and 20 in, the amounts falling on the two watersheds were approximately equal. Rainfall within this range can be expected once every two years. For this recurrence interval both Plan I and probability curves show the amount of runoff from W-III to be greater than that for W-V. For each of the three years when the rainfall was greater than 20 in, the amounts falling on W-V exceeded those on W-III by approximately 1.25 in. This probably accounts for the fact that the probability curve values of runoff are greater for W-V than for W-III for those recurrence intervals when these higher amounts of rainfall might be expected.

The foregoing discussion illustrates one reason why direct relationships between amounts of rainfall and amounts of runoff are preferable to probability curves in making comparisons between amounts of runoff from two watersheds. Where such relationships cannot be established, however, probability curves can be expected to give fairly accurate results.

SUMMARY

The principal conclusions that have been made in this analysis are briefly summarized as follows:

1 Comparisons of surface runoff from two watersheds should be reduced to the common denominator of normal

rainfall if the effect of changed land use is to be measured.

2 Relationships between rates of rainfall and rates of surface runoff cannot be established unless the many other factors that affect surface runoff can be controlled. In some localities it is possible to establish relationships between amounts of rainfall and amounts of runoff, provided that these amounts are for a period of months and not for individual storms.

3 Direct comparisons of peak rates of surface runoff from two watersheds can seldom be made unless corrections are applied for dissimilar rainfall. This is also true for direct comparisons of runoff amounts.

4 Relationships between surface runoff from two watersheds can be determined by comparing probability curves computed from the runoff data for each watershed. The probability curve selected should be the one that best fits the plotted points and at the same time expresses a relationship that seems reasonable.

5 Relationships expressed by mathematical curves should not be extrapolated much beyond the range of the experimental data unless a careful study is first made of all factors involved.

REFERENCES

1 For more complete descriptions, see "Hydrologic Data, Central Great Plains Experimental Watershed, Hastings, Nebraska, 1938-40." USDA Hydrologic Bulletin No. 3, 1942.

2 Rainfall Intensity-Frequency Data, by David L. Yarnell, USDA Miscellaneous Publication No. 204, 1935.

3 Frequency Determinations, by Dr. A. E. Brandt. Unpublished manuscript.

4 The Effect of Conservation Practices on Peak Rates of Runoff, by Ralph W. Baird. The Texas Engineer, August, 1946, vol. 16, no. 8, pp. 8-15.

5 Simplified Plotting of Statistical Observations, by E. J. Gumbel, Trans. American Geophysical Union, August, 1945, vol. 26, part I, pp. 69-82.

6 Estimating Peak Rates of Flow for Various Recurrence Intervals Using Frequencies and Probability Paper Developed by Prof. E. J. Gumbel, by W. D. Potter. Unpublished manuscript.

7 Theoretical Frequency Curves and Their Application to Engineering Problems, by H. Alden Foster. Trans. American Society of Civil Engineers, 1924, vol. 87, pp. 142-203.

8 A Study of Methods of Estimating Flood Flows Applied to the Tennessee River, by Thorndike Saville, U.S. Geological Survey, W.S.P. 771, pp. 398-420.

Discussion by Ralph W. Baird

MEMBER A.S.A.E.

THE problem analyzed in Mr. Potter's paper is one that has been given much thought by all those concerned with runoff from agricultural lands. The numerous factors other than rainfall affecting rates and amounts of runoff have made the application of methods available for other studies difficult or impossible to use in these particular problems.

All of us are very much interested in an attempt to adapt methods generally accepted for other studies to this particular problem. Mr. Potter's work is a major contribution to the tools that are available to the hydrologists who are working on this subject.

The difficulties inherent in the problem are frequently overlooked or not well understood. The effect of land use on runoff rates and amounts will vary greatly with the time of year and condition of the vegetation, previous rainfall, time since previous tillage operations and the nature of the storm.

From results of the work at the Blacklands Experimental Watershed at Waco, Tex., there is little indication of an appreciable decrease in the amount of runoff from agricultural lands in this area with changes in land use. For certain individual storms this may not be true, but for longer periods and for those storms with runoff amounts causing floods of medium to extreme size, this does seem to be the case. Land use changes together with terraces have had a fairly consistent effect on the peak rates of runoff. As there has been no consistent reduction in the amounts of runoff, this reduction in peak rates must be due largely to temporary storage, either in the soil or by water held behind terrace ridges. For storms producing the larger floods, field conditions are such that the storing of a large amount of additional water in the soil is improbable. It then seems reasonable to credit the temporary storage in terrace channels with the major portion of the reduction in peak runoff rates. This effect changes with the character of the storm and the depth of flow in terrace channels, but is one that will have some effect unless the terraces are overtopped or broken.

Because of differences in soils, climate, and topography, results obtained from the Hastings areas should reasonably be expected to differ from those at Waco. At Waco, with a heavy Houston black clay, there are frequently periods when the soil profile to a depth of 8 or 10 ft has all moisture deficiencies satisfied and a very high percentage of any rainfall occurring after this condition has been reached, appears as surface runoff. This condition has been true on native meadow lands, as well as on cultivated fields. On the more permeable soils, with less rainfall, this condition should seldom, if ever, be expected on the Hastings areas.

Determining the effects of certain land-use treatments is difficult when natural areas of considerable size are used and results from plots fail to answer many important questions. The cost of equipping and operating such runoff measuring stations makes it necessary that as much information as possible be obtained from a limited number of stations. Methods of analysis are of vital importance and even after analysis the hydrologist must use considerable judgment. If results seem unreasonable or not in accordance with other phenomena, the method of analysis must be carefully reconsidered.

Another fact frequently given insufficient emphasis is that the effect of land-use treatments can be expected to have a maximum effect for small storms following dry periods and a minimum effect for larger storms or for intermediate-size storms following periods of heavy rainfall.

The question to be answered is that of the effect of different land uses on surface runoff. Without very extensive field installations, I do not know of a better arrangement for this purpose than that used at Hastings. If a long period of record is available the use of probability curves appears to be a satisfactory method of analysis. If the record is short, there may be a serious error when the curve is extended to include 25 or 50-yr frequencies. The runoff measured for the period of record can easily be different from the normal even though the rainfall rates and amounts fit well into the long-time pattern.

For peak rates of runoff the procedure used on the Waco data seems quite satisfactory to me. The differences between the two areas are quite well defined, the results from a few storms can be used as a measure of the effect of land use with some degree of reliability and with each additional storm there is an increase in the assurance that the curve is approaching a correct long-time position. With use of the probability method, several years of record would be required for an approximation.

The method used by Mr. Potter fits very well into the problem of determining the frequency of peak runoff rates, and covers a part of the problem not discussed in the method used on the Waco data. Considerable work has been done on this problem of frequency of peak rates of different magnitudes. If the effect of land use can be determined for a number of storms throughout the range that can reasonably be expected, these data can be used when land use has been changed.

There is no substitute for a record of considerable length if we use any of the methods considered by Mr. Potter or any others that I know of. If a period of record covers the high rates fairly well, it probably will give results that are safe to use following the method used at Waco. Use of the frequency method would be much more questionable if the rates occurring during the period of record seem to be above or below the normal.

At Waco, analyses of records of amounts of runoff have not yet led to definite conclusions. It would seem that the application of adjustments for rainfall amounts is either more difficult than the adjustment for rainfall intensity or that soils, crops, and previous rainfall have a greater effect on the amount than the rate of runoff.

RALPH W. BAIRD is a project supervisor, Soil Conservation Service (Research), U. S. Department of Agriculture.

The methods outlined by Mr. Potter will be tried with the Waco data as soon as possible. From this method and others that have been used we should be able to develop reliable methods for recording the effects of different land-use practices. In the work of developing these methods we should also obtain some factual data that will be of value to the engineer in planning conservation and flood control works.

Discussion by L. L. Harrold

MEMBER A.S.A.E.

STUDIES of the effect of land use on surface runoff have received much attention in agricultural fields in recent years. As the Soil Conservation Districts needs for planning soil and water conservation programs increase, these studies attain greater importance. It is, therefore, timely that progress along these lines be presented to the agricultural engineering field.

Mr. Potter's paper does much towards explaining the complexity of the problem when only short-term data are available. The various procedures he used for comparing the effect of different land use on runoff rates and amounts have been applied individually by others for numerous statistical problems. It is well that the different procedures be focused on the same problem. In this way, their merit in this field can be compared. Consequently, one procedure might prove to have an advantage and could, therefore, be recommended for general use.

I have also been concerned with the analysis of runoff data to show land-use effects. These studies are being made at the North Appalachian Experimental Watershed near Coshocton, Ohio. This is a USDA Soil Conservation Service research station and is operated in cooperation with the Ohio Agricultural Experiment Station. The topography, soils, and land use are typical of that in southeastern Ohio, western Pennsylvania, West Virginia, and parts of Kentucky.

In this brief discussion all of the essential features of Mr. Potter's paper cannot be covered. I will confine my remarks mostly to the adjustments of peak rate curves to normalcy. Land use on the watersheds for which data are presented herein was identical for only 3 yr. I feel that this period was too short to establish recurrence (frequency) relationships for either peak rates or runoff totals. Incidentally, Hobbs[1] and perhaps others do not agree with this.

The author suggests that these short periods be tested for normalcy by comparing the number of excessive storms by months, the maximum rainfall intensities, and the amount of seasonal rainfall for the initial period with that for long-time records in the vicinity of the experimental area. He also recognizes that rainfall factors are not necessarily the dominant ones affecting runoff. Although this last fact has been apparent for some time, attempts have been made to adjust short-term records to a long-term normal by comparing the short rainfall record with long Weather Bureau records. In fact, I did this a few years ago[2]. Since that time, however, records from watersheds at this experiment station indicate that the rainfall factor alone is not a sufficient criterion to judge the normalcy of sampling periods.

For our soils, the volume of empty pores in the soil at the beginning of the storm is a very important factor governing runoff. Of course, this varies with volumes of antecedent rainfall entering the ground and moisture disposal factors such as evapo-transpiration and water percolation to greater depths. Maximum rainfall does not always produce maximum runoff. Some of the greatest flood peaks are caused by storm rainfall of less than greatest intensities (Table 1).

A classic example of the same rainfall rates causing both low and high runoff peaks was found in 1945. On September 20, a 15-min maximum rainfall rate of 2.52 in per hr resulted in a flood peak of only 0.02 in per hr. In contrast, on September 23 a rainfall of 2.44 in per hr caused a flood peak of 1.73 in per hr — the greatest in 10 yr of record. The data for the former storm are given in columns 2 and 5, line 8. The latter are given in columns 3 and 4, line 1, of Table 1.

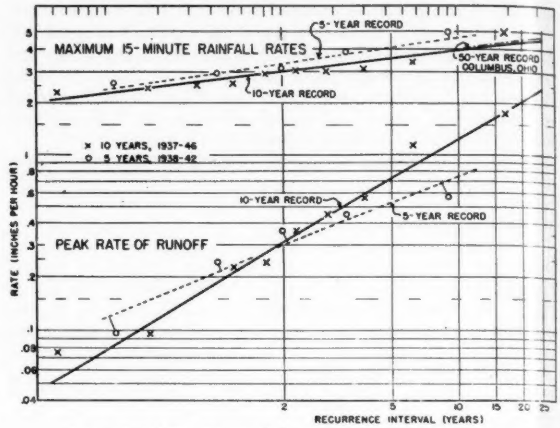


Fig. 1 Rainfall and runoff for station watershed No. 10, Coshocton, Ohio, 1937-46

The data in columns 2 and 3 of Table 1 are shown graphically in Fig. 1. The method of plotting and the determination of recurrence intervals is the same as that used by the author[3]. Also shown on this figure is the rainfall-frequency line derived from the 50-yr rainfall record at Columbus, Ohio. It will be noted that there is no practical difference between the rainfall line developed from the 10-yr record at Coshocton and that from the long-time record. The rainfall line from this short record (10 yr) may, therefore, be considered normal. Yet I would not conclude definitely that the flood peak line for the 10-yr record is normal.

TABLE 1. MAXIMUM ANNUAL RAINFALL RATES AND CORRESPONDING RUNOFF PEAK AND GREATEST ANNUAL RUNOFF RATES AND CORRESPONDING MAXIMUM RAINFALL RATES, 122-ACRE WATERSHED, NO. 10, 1937-46

	Greatest annual rainfall and runoff rates		Actual rainfall rate‡ causing	Actual runoff peak in
Order No.	Maximum rainfall rate, ‡in/hr	Runoff peak, in/hr	runoff peak (col 3), in/hr	storm listed in (col. 2), in/hr
1	5.00	1.73	2.44	0.21
2	3.40	1.15	2.31	.08
3	3.15	.563	2.04	.06
4	3.08	.455	4.32	.33
5	3.06	.368	2.96	No record
6	2.96	.242	2.84	.37
7	2.60	.229	.76	No record
8	2.52	.100	.25	.02
9	2.44	.096	2.60	.02
10	2.32	.076	.88	.02

‡Average for 15-min period.

In Fig. 1, you will note 5-yr (1938-42) lines for rainfall and runoff. The rainfall line lies above and is somewhat parallel to the 50-yr normal line. The 10-yr line coincides with the normal. If, then, the 10-yr runoff peak line could be considered normal, then one would expect the 5-yr curve to lie above and be parallel to the 10-yr line. It does not work out this way. The runoff line for the 5-yr period lies considerably below the 10-yr line for the less frequent recurrences. On the basis of the relationship of the 5-yr rainfall line to the 10-yr rainfall line, one could not adjust the 5-yr runoff line to get a 10-yr line or a normal line.

The hydrologic observations made on the agricultural watersheds at the Coshocton experiment station indicate that the full effect of land-use practices will not show up right away. It is expected that the changes will be gradual. In 20 yr the contrast between conservation practices and poor farming practices ought to be greater than at the end of 10 yr after

L. L. HARROLD is a project supervisor, Soil Conservation Service (Research), U. S. Department of Agriculture.

[1]Hobbs, Harold W. Runoff Behavior of Small Agricultural Watersheds under various Land Use Practices. Trans. Amer. Geo. Union Vol. 27, No. VI, pp. 891-894. December 1946.

[2]Harrold, L. L. Flow from drainage basins determined by short-term records. Proc. Amer. Soc. Civil Engineering. April 1945.

[3]Brandt, A. E. Frequency Determination. Unpublished manuscript.

improvement. If this is true, the curve or line relating one watershed to another should appear in different positions each year or so. This would continue until the maximum difference is attained.

Mr. Potter's work may well serve as a guide for comparative studies of this type. When we know more about the hydrology of soils and agronomic factors involved in the rainfall-runoff relationships, more accurate determinations will be possible.

Closing Discussion by W. D. Potter

MR. BAIRD'S criticism that probability curves based on short records are apt to be considerably in error when extrapolated to recurrence intervals of once in 25 or 50 yr would apply equally well to all of the analytical procedures considered in my paper. All of the procedures give fairly satisfactory results within the range of the experimental data. The one used by Mr. Baird does not eliminate the necessity for extrapolation. In his paper he determines the effect of land use on peak rates that might be expected during a 3-yr period but he would have had to extrapolate the relationships that he established if he were to answer the fieldman's query as to the effect that might be expected on peak rates that occur once in 15, 25, or 50 yr.

I do not mean to imply that probability curves are to be preferred over other analytical procedures. Mr. Bauer has shown that the method developed by Mr. Baird gave excellent results when applied to the amounts of runoff considered by storms instead of by 6-mo periods, and I have no doubt that equally good results can be obtained when the method is applied to the Hastings peak rates. I do wish to emphasize, however, that any relationship expressed by a mathematical curve is apt to be in error when extended beyond the range of experimental data and that such an extrapolation should not be attempted unless a careful study is first made of all factors involved.

Mr. Harrold states that "land use on the watersheds for which data are presented was identical for only 3 yr." This statement would lead one to doubt as to whether or not his 5 and 10-yr runoff curves were based on comparable data. Assuming that the land use was constant for the 5 and 10-yr periods and that the runoff data were, therefore, comparable, Mr. Harrold has applied only one of the three rainfall tests outlined in my paper. The magnitude of high intensity rainfall could be normal for a given period and yet the number of high-intensity storms and the total amount of rainfall could be considerably below normal. If such were the case, the chances of a high intensity rain occurring when the soil was nearly saturated from antecedent rainfall would certainly be less than if the number of high intensity storms and the total rainfall had been normal. I realize that these last two tests are not as reliable as detailed information on such factors as antecedent rainfall, soil moisture, storm pattern, and cover would be. They should, however, furnish an indication as to whether or not the chances were normal for high intensity storms to occur when the watershed was in a condition to produce maximum runoff. It may well be that other tests should be applied, but with the present system of Weather Bureau reporting, the three that I have outlined appear to be the only ones that are readily available.

Safflower—Our New Oil Crop

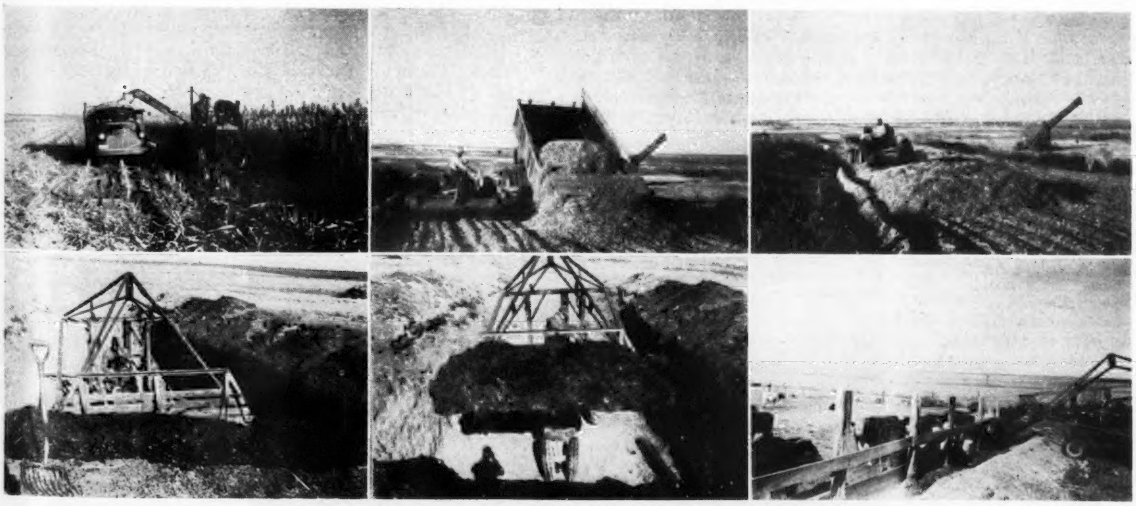
IN THE past safflower had no market in this country. Now it has. Forty-nine Montana farmers grew 4,000 acres of safflower last year. Yields were quite good, averaging 600 lb of seed per acre, or, on the basis of 40 lb to the bushel, an average of 15 bu, worth today some $54 to $60 an acre.

Safflower produces branching plants 28 in tall and quite uniform. The stem is heavier and tougher than the stem of flax. The boll, many of which occur on each plant, is as large around as a two-bit piece. Several seeds are borne inside of each boll. They rest in a bed of white floss. Leaves and the boll both have spines; that is, on varieties now in use. This fact alone in the past made the crop unattractive to nearly all United States farmers who heard of it, but the use of combines for harvesting at the present time has removed that objection.

Safflower poses no serious question of competition with flax in the humid areas where flax prospers. It seems to thrive in areas of less rainfall, where precipitation normally is only 12 to 15 in annually and where flax generally does not yield so well. Normally, too, under "dry-land" conditions, safflower does as well as wheat or better.

Like flax, safflower does not compete well with weeds. However, it is troubled little either by disease or by insects. —Chemurgic Digest, December 31, 1947.

SILAGE HARVESTING, STORAGE, AND FEEDING MECHANIZED



Don Christy sent these pictures taken on the Christy farm near Scott City, Kansas. *Upper left:* Cutting and loading silage in the field. *Upper center:* Dumping silage in the pit silo. *Upper right:* Spreading and packing silage at the pit. *Lower left:* Scooping silage from the pit for feeding. *Lower center:* Backing out of pit with scoop load of silage. *Lower right:* Dumping silage in feed racks. The scoop shown in the lower pictures carries about 1,000 lb of silage, enough to fill a large feed bunk. Christy says that in normal weather, with the feed bunks handy to the silos, one man should feed 1,000 head per day, which he says is normally too many to have in one bunch

Water Spreading for Ground-Water Replenishment

By Dean C. Muckel

THIS paper deals with that method of water conservation known as "water spreading." It is defined as the practice of diverting water from natural stream channels and spreading it over porous lands, thereby giving it opportunity to sink into the ground and eventually become a part of the main ground-water body. The term "water spreading" has also in recent years been used in some localities to describe the practice of diverting stream flow during flash floods to pasture and other lands for the purpose of irrigation. Although the two spreading systems may be similar in design, their purposes are definitely different; and as the term is used in this paper, it applies only to the practice of diverting for replenishment of the underground water supplies. Such spreading is used in areas where pumping from wells is a major means of obtaining water.

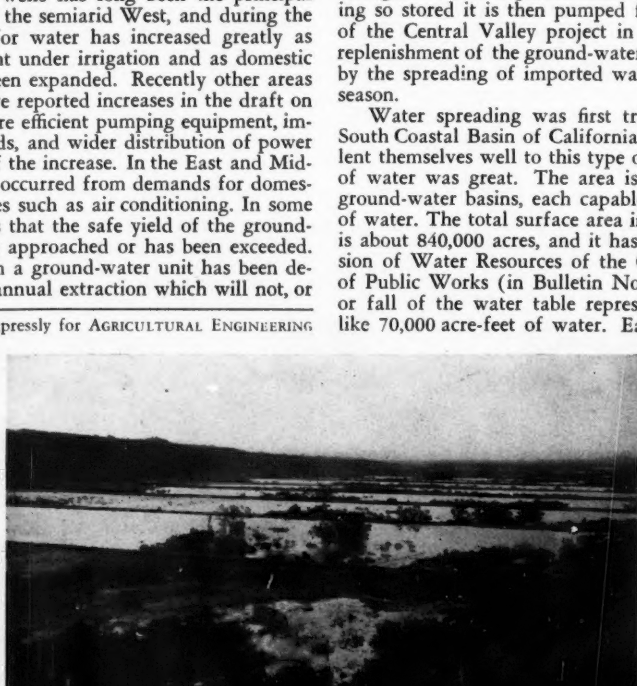
Spreading for replenishment of the ground-water supplies deals with much greater quantities of water than those required for irrigation. Water is applied to an area in such quantities and for such long periods of time that the proportion of water retained in the root zone is negligible. The purpose is to stimulate percolation so as to replenish the ground-water supplies and raise the water table, whereas in irrigation an application a few inches deep per irrigation or 2 to 4 ft per year is adequate. In spreading for replenishment of ground water, as much as 5 to 8 acre-feet per acre is put into the ground in a single day. The total seasonal amount which can be spread is of course dependent on amount of water available, the capacity of the spreading system, the capacity of the underground basin, and the length of time the water is available.

The need for water spreading has been apparent in many localities for many years, and it is rapidly becoming apparent in others. Pumping from wells has long been the principal source of water in parts of the semiarid West, and during the past decade the demand for water has increased greatly as more land has been brought under irrigation and as domestic and industrial uses have been expanded. Recently other areas throughout the country have reported increases in the draft on ground-water supplies. More efficient pumping equipment, improved well-drilling methods, and wider distribution of power have accounted for some of the increase. In the East and Middle West these drafts have occurred from demands for domestic, industrial, and other uses such as air conditioning. In some places there are indications that the safe yield of the ground-water unit is rapidly being approached or has been exceeded. The term "safe yield" from a ground-water unit has been defined by Conkling[1] as "the annual extraction which will not, or does not (1) exceed the average annual recharge, (2) so lower the water table that permissible cost of pumping is exceeded, or (3) so lower the water table as to permit intrusion of water of undesirable quality." The safe yield of a ground-water unit or basin is difficult to determine in most cases, but reliable evidence of the adequacy of a ground-water supply is reflected by the rise or fall of the ground-water levels. The general equation, Average Inflow = Average Discharge ± Change in Storage, applies to ground-water basins, but evaluation of the items is extremely complicated. Inflow may be broken into surface flow, underflow, importation and precipitation on the surface; the discharge may be divided into surface flow, underflow, consumptive use (including soil evaporation), and exportation. The source of all water is of course from precipitation, and man has no control over its amount or distribution. He can, however, practice water conservation and build dams, channels, and other structures to distribute the water after it reaches the earth. Consumptive use represents principally the water used by plant growth—either cultivated or native—and domestic and industrial uses. It is the item which has been increased considerably by man's action and has caused the inflow and outflow sides of the equation to get out of balance and be reflected in a lowering water table.

The use of water spreading, like most other methods of conservation, is intended to increase the ground-water inflow, reduce the discharge side of the equation, and retain as much of the water as possible within the limits of the ground-water unit. In a few cases water spreading has been utilized to make effective use of a well-defined ground-water basin for the storage of imported water. The city of Los Angeles has at times utilized the San Fernando Valley ground-water basin for the storage of water imported from the Owens Valley. After being so stored it is then pumped from wells as needed. Plans of the Central Valley project in California also contemplate replenishment of the ground-water supplies in overdrawn areas by the spreading of imported water during the non-irrigating season.

Water spreading was first tried on a large scale in the South Coastal Basin of California because there the conditions lent themselves well to this type of conservation, and the need of water was great. The area is composed of many distinct ground-water basins, each capable of holding large quantities of water. The total surface area in which ground water occurs is about 840,000 acres, and it has been estimated by the Division of Water Resources of the California State Department of Public Works (in Bulletin No. 45) that every foot of rise or fall of the water table represents a change of something like 70,000 acre-feet of water. Early settlers found the water table at high levels within convenient pumping lifts. More and more wells were put down until now more than 90 per cent of all water developed locally is derived by pumping from wells. In some basins the safe yield has been exceeded and in others it is rapidly being approached. The ground-water supplies are replenished naturally by rain falling directly on the valley floors, by seepage from a stream traversing the valleys, and by the return from irrigation.

Some of these sources have been necessarily curtailed by the straightening and paving of flood



A series of cross walls built across a deep cut made by a stream as it emerges from its canyon. The walls are relatively porous and consist of rocks bound together with heavy hog wire. Their height and spacing are such that the flood waters will spread over the entire bed

This paper was prepared expressly for AGRICULTURAL ENGINEERING as a contribution of the Subcommittee on Ground Water, Committee on Agricultural Hydrology, Soil and Water Division, American Society of Agricultural Engineers. It was prepared under the direction of Geo. D. Clyde, chief, division of irrigation and water conservation, Soil Conservation Service, U. S. Department of Agriculture.

DEAN C. MUCKEL is irrigation engineer, division of irrigation and water conservation, Soil Conservation Service, U. S. Department of Agriculture.

[1]Conkling, Harold. Utilization of Ground-Water Storage in Stream System Development. American Society of Civil Engineers Proceedings, January, 1945.

channels and the construction of streets and storm sewers, but spreading areas have been developed to augment the natural methods of replenishment.

Rainfall in this area is very erratic, varying greatly in yearly total and seasonal distribution. There are instances where more than an average seasonal rainfall has occurred in a single storm. The surface runoff is consequently great at such times, and if not held back by dams or stored underground, much water may be wasted into the ocean. On the other hand, there are years when the rainfall is less than the water requirement of the area. Some form of storage is necessary under these conditions to carry over water collected in wet periods for use in dry periods. The underground basins serve this purpose.

Areas suitable for spreading were found to exist at the mouths of the many canyons where they debouch from the mountains. Here the streams have built up relatively steep debris cones by dropping their loads of boulders, gravels, and sands as they struck the flatter slopes of the valleys. These debris cones vary from a few acres to more than 5,000 acres, depending on the size of the streams. Because of the coarse material of which they are composed, the lands are not particularly suitable for cultivation and are in general classed as waste. They are porous and have high rates of infiltration, and consequently are well adapted to water spreading. Diversion works are placed in the stream channels, and the water is diverted to prepared spreading systems. Water spread on these cones percolates downward and eventually feeds the pumping areas of the valley lands. The actual procedure of diverting and spreading water on the debris cones is not simple. It involves the handling in most cases of debris-laden flood flows. The cones are still in the process of formation and are consequently unstable. The streams, if uncontrolled, meander over the surfaces and cause great damage in times of heavy floods.

One of the most important—probably the most important—feature of a spreading area is the rate at which the water will enter the soil. The capacity of a spreading area is directly proportional to this rate. It varies with the soil type, condition of the soil surface, and other factors. The Division of Irrigation and Water Conservation of the Soil Conservation Service has long been interested in water spreading as a means of water conservation and in 1930 started experiments to determine the relative rates of percolation obtained by different methods of spreading. Because practically all spreading being done at that time was located in southern California and on porous debris cones, these tests were carried on under those conditions. There were then, as now, four general methods of spreading the water over the land surface. They are (1) the basin method, (2) the furrow or ditch method, (3) the flooding method, and (4) the use of pits or shafts. Each has its own advantages and disadvantages, and with the exception of the last named each is widely used. They are often combined, and it is not uncommon to find all four methods used in a single spreading system. Generally the selection of a method depends on the typography of the soil surface, the general slope of the land, the amount of land available, and whether the water is silty or clear.

IN THE BASIN METHOD WATER IS IMPOUNDED

In the basin method of spreading, the water is impounded in a series of small basins formed by dikes or banks. The basins are so arranged that the entire area may be submerged during spreading operations. The dikes often follow the contour lines and are provided with outflow facilities so that excess water from the basin highest in elevation will escape into the one next lower. This method of spreading is used where the ground surface is irregular and spotted with numerous shallow gullies and ridges. The basins prevent the water from collecting in the gullies and running off before it has a chance to penetrate into the soil. The basin system is not recommended where the water carries silt or foreign material.

In the furrow or ditch method, the water is passed through a series of furrows or ditches somewhat resembling an irrigation system. The ditches are shallow and flat-bottomed, spaced closely one to another so as to expose the maximum percolating area. The ditches are usually arranged according to one of three patterns. In the first, lateral spreading ditches, at right angles to the main canal, are extended parallel to each other at frequent intervals. In the second pattern, instead of diverting from a main canal, the canal may be divided into two separate ditches, these two ditches being then divided into four smaller ditches. Division is continued until the flow in the ditches has dwindled to mere trickles and finally disappears. The third pattern is commonly called the contour ditch system. Here the water is spread through one ditch that follows approximately the contour of the ground surface. As the ditch comes to the limits of the area provided for spreading, a sharp switchback is made. Thus the ditch is made to meander back and forth across the land, gradually approaching the lower part of the spreading area. The ditch system has the advantage of flowing water in event a silty supply is used. Difficulty of maintaining flat bottoms in the ditches has been experienced in some systems owing to the tendency of the flowing water to cut and collect in narrow streams.

In the flooding method of spreading, it is implied that the water is passed over the land in a thin sheet and at a slow velocity. If conditions permit, this is the ideal method. The soil can remain in an undisturbed state, and it has been found that undisturbed soils with native vegetation remaining intact ordinarily absorb water at a faster rate than disturbed soils. It is realized that few areas exist where flooding can be accomplished through a spreading area owing to the roughness of the land surface, but the principle of flooding should be carried out wherever possible.

USING SHAFTS AND PITS FOR WATER SPREADING

The fourth method of spreading—that of utilizing shafts or pits—does not follow strictly the definition of water spreading, but it serves the same purpose of recharging the underground supply. It is not used extensively because of its high cost and other limitations. Shafts or pits are seldom sunk primarily for this purpose; rather, use is made of abandoned gravel pits, wells, or other existing holes. The advantage of pressure head or depth of water in a shaft or pit is utilized in this method. Silty water is, of course, to be avoided. Most of the information obtained so far does not indicate that any widespread or general use of this method can be expected, although isolated installations have been reported as being successful.

In 1937 the U. S. Department of Agriculture published the results of experimental work done in southern California in Technical Bulletin No. 578, "Spreading Water for Storage Underground." Since issuance of this publication, the need for spreading has extended to other areas considerably unlike the southern California conditions, particularly with reference to soils. Spreading is now being contemplated on older, more consolidated soils and even in areas where hardpans and claypans exist. Water differing in quality is also being considered as a source of supply. This has multiplied the problems of spreading.

The infiltration rate of the older, more developed soils of finer texture can, of course, be expected to be less than that of gravels or sandy soils, but there are other complications. A notable example is that of San Joaquin Valley where it is proposed to spread imported water so as to replenish the overdrawn pumping areas. The location of the supply canal and of the areas needing replenishment are such that spreading areas must be located on sandy loams, loams or soils of finer texture, and, incidentally, on lands highly valued for agricultural use. Preliminary field studies made on these soils by the North Kern Water Storage District (H. L. Haehl, unpublished data 1943) revealed that while the infiltration started at a satisfactory rate, it rapidly decreased until after a few weeks of spreading practically no water entered the soil. A search of the literature showed that considerable experimental work was being done on the problem of infiltration, but in nearly all cases the work was done in connection with infiltration of rainfall or irrigation water and consequently the water was applied for short runs only. In spreading, water may be applied continuously for months at a time. An intensive series of ex-

periments[2] was started to disclose the cause of the rate decrease and to discover, if possible, practical ways of overcoming or at least retarding the decrease. A group of nine test ponds formerly operated by the North Kern Water Storage District was put in operation and thirty-five others were constructed. Fifteen were in isolated locations on different soil types and served with different water supplies. The remaining ponds were located in two groups on the two predominant soil types of the Kern area. In addition, there were available records from spreading on seventeen large spreading areas, ranging in size from a few acres to over 50 acres.

The test ponds were given a variety of treatments, which are too numerous to list, but they included different cultural treatments, mulches, various grasses, chemical treatments, and different methods of operating with alternate wet and dry periods, shallow, deep and fluctuating water depths. The effects of all treatments were checked against the rates obtained on undisturbed check ponds. Some of the experiments were not considered to be practical on a large scale; rather, they were of an academic nature though involved in the search for a practical solution of the problem. Numerous undisturbed soil cores were taken in the field and run for weeks without interruption in the laboratory with waters having different characteristics and with different treatments. Some cores were run under sterile conditions and were equipped with manometers, and the permeability of short segments was calculated. Equipment for taking soil cores encased in transparent lucite cylinders 4.5 in in diameter and 16 in long was developed by the Regional Salinity Laboratory at Riverside, Calif.[3,4].

While it cannot be claimed that the final answer has been found, it is felt that much valuable information has been obtained through the operation of the laboratory and through field tests. Some of the results are discouraging, while others are encouraging. It was found early in the program that the infiltration rate decline is caused primarily by conditions within the top foot or less of soil where the organic matter is found. This fact was demonstrated by both laboratory cores and tensiometers set in the field ponds. It is encouraging because it gives some hope that a practical treatment to reduce the decline in rate may be found.

At the present writing, it appears that spreading the water in a shallow depth (one or two-tenths of a foot) on a vegetated area is the most likely to give the most consistently high infiltration rates. It is also evident that the soil must be given a drying period if it is to recover the initial infiltration rates after the decline has occurred. The drying period should be started before the ultimate decline has occurred to insure the best results. *(Continued on page 78)*

[2]Agencies participating or who have participated in this study are the North Kern Water Storage District; U. S. Bureau of Reclamation; Arvin-Edison Water Storage District; Rubidoux Laboratory and Regional Salinity Laboratory, USDA: California Division of Water Resources, and the Division of Irrigation and Water Conservation, Soil Conservation Service, USDA.

[3]Allison, L. E. Effect of Microorganisms on Soil Permeability. Manuscript prepared for publication.

[4]Permeability Test. AGRICULTURAL ENGINEERING, April, 1945.

Mechanical Ventilation of Ear Corn

By R. E. Johnson and Virgil Marvin
MEMBER A.S.A.E.

OBSERVATIONS on forced air ventilation for drying ear corn were made this past fall on the farm of Dwight Wise near Fremont, Ohio. The project was conducted by the farm power department of The Toledo Edison Company with Mr. Wise cooperating.

A new grain storage building had been constructed by Mr. Wise, the grain storage portion of which has six bins 10x10x13 ft, with slatted floor and tight sides. Forced air can be used on all the bins.

On October 8 approximately 700 bu of ear corn (by volume) were put into two of the bins. The average depth of the corn was approximately 9 ft.

Random samples of corn from the picker averaged 40 per cent moisture (wet basis) in the kernels.

A 34-in propeller-type fan powered by a 3-hp motor was used to force air through the bins. The static pressure was 0.3 in of water. From the fan manufacturer's rating, the air delivery was approximately 14576 cfm. This amounted to 20 cfm per bu of ear corn.

Mr. Wise operated the fan intermittently during the 24-day period. The total time of operation was 232 hr with an energy use of 600 kw-hr (approximately 1 kw-hr per bushel).

Climatological data were recorded every 2 hr during the 24-day period.

The graph shows the per cent of moisture of the corn, mean air temperature, and per cent of mean relative humidity. During the first half of the period drying conditions were favorable; the latter half was not so favorable. The mean temperature for the month was 8.8 F above the normal temperature of 51.6 F. The mean relative humidity was 70 per cent.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

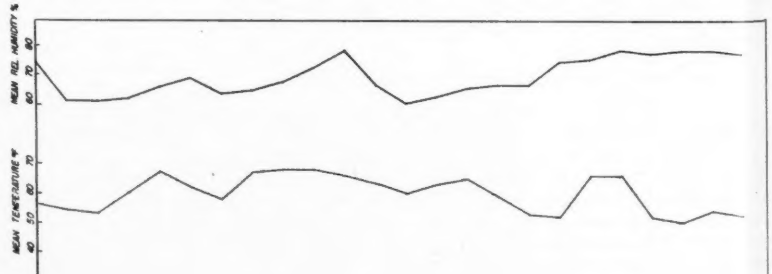
R. E. JOHNSON and VIRGIL MARVIN are, respectively, manager and field supervisor, farm power department, The Toledo Edison Company.

CONCLUSIONS

Ear corn was successfully dried from 40 per cent moisture (wet basis) down to 19 per cent (wet basis).

By the use of forced air from corn conditioning it would be practicable in this area to pick corn relatively early in the season and plant the corn ground to winter wheat.

The factors of temperature and humidity, as they influence drying, are well established. However, a third factor, air velocity through the product, is an important factor in the rate of drying. The air velocity factor should be in mind when calculations are made on the volume of air to be used. As great a volume of air per bushel, as is economically feasible, should be used in order to obtain as high a velocity as possible through the bins.



This graph shows the data taken during observations of ear corn drying on the Dwight Wise farm

Durability of Concrete Drain Pipe

By W. L. Powers
MEMBER A.S.A.E.

THE recent support price for making burned clay building blocks as well as the AAA payments for field drainage practices has caused increased interest in the durability of concrete pipe as a substitute for burned clay drain tile. The latter should meet current specifications of the American Society for Testing Materials.

A report of inspections and tests of concrete drain pipe and concrete blocks after 10 years' exposure in eight alkali-bearing projects was made by Williams and Furlong in 1926[1], in which they concluded that "the best quality of concrete will deteriorate when exposed to severe alkali attack and that installations of concrete in soils containing more than 0.1 per cent of the sulfate type should be preceded by an examination of surrounding conditions. The use of concrete pipe in soils containing alkali salts of the sulfate type is hazardous in view of the fact that the best quality of drain tile has been disintegrated." The resistance was found to vary with the consistency and richness of the mix and method of manufacture, and tar coating or grouting did not insure protection. Tests after 10 years of exposure showed the crushing strength reduced from 1870 to 1610 lb in fresh water at Columbia, Mo., and from 1655 to 1225 lb where exposed to alkali water in eight test areas. Disintegration was found to be primarily due to chemical action between the salts in the solution and the constituents of the cement, though physical disruption caused by expansion of some crystallization of salts in the pores appeared to be a factor. Curing pipe in water vapor at 212 F increases its resistance[4].

Effect of Alfalfa Roots on Durability of 6-in Concrete Pipe. An experiment was started in April, 1932, to test the notion that alfalfa roots would weaken concrete pipe by extracting lime therefrom. Five lots of ten pipes were included in the experiment:

- Lot C stood empty on a plank outside the greenhouse.
- Lot A was filled with Willamette silty clay loam soil, limed and cropped to alfalfa.
- Lot B was filled with Willamette silt loam and limed.
- Lot D was filled with soil and cropped.
- Lot E was filled with soil and fallowed.

Breaking tests with five pieces of each lot were made at the end of 8 years exposure, on October 8, 1940. The other half was kept in the test for some 7½ years longer and tested March 6, 1947. Tests were made by applying pressure uniformly top and bottom with sand bags, each seated to contact one-fourth the surface area. The bearing strength was determined by an Olsen materials tester in the laboratory of the Oregon Engineering Experiment Station. Statistical analyses of the tests support the following conclusions:

1 Slight impairment of the pipe was caused by alfalfa roots only when the soil was unlimed.

2 Pipe exposed on a plank out of doors gained strength during the second term of exposure.

To test the intensity of acidity in the soil contained in the different lots of pipe, composite samples were made, and the pH values determined for the results are as follows:

Lot	*Treatment*	*pH*
A	Lime and alfalfa	7.37
B	Soil limed	7.11
D	Soil and alfalfa	6.13
E	Soil fallowed	6.44

The increasing acidity from alfalfa root action without lime seems to correlate with a decreasing strength of pipe. In other experiments by the author it has been noted that active alfalfa roots tend to bring the soil reaction in their vicinity to pH 6.0, approximately.

Durability of Concrete Pipe in Acid Soil. When the experimental tile drainage system was designed for installation in tideland at the Astoria field station by the author in 1916, concrete drain pipes were included for use in one lateral. The soil there is Bayside (peaty) silty loam with a pH of 4.2 on the surface and 4.8 in the subsoil. Recently one rod length of this lateral was replaced by Supt. H. B. Howell, and several pieces that were removed intact were secured for bearing strength tests. These 4-in pipes, apparently of hand-tamped concrete, after 30 years use in acid soil gave the following results as to crushing strength in pounds per pipe:

270 195 340 220 260 195 225 - average, 246.5

These pipes could be crumbled at the ends with the thumb and fingers. After drainage of this tideland, iron oxide precipitates in the drains and these old pipes were coated in the lower part of the inside with this material.

Farmer Experience with Concrete Drain Pipe. Recently a questionnaire was sent to farmers who had been given assistance in the design and survey of drainage systems as an extension service. Thirteen out of 100 reporting stated that they had experience with concrete pipe, and of these six reports were favorable. The experience extended up to 20 years, and some indicated that in the earlier years concrete pipe were not as well made as at present. The less favorable reports seemed to have come with experience of the pipe in distinctly acid soil approaching intensity of acidity such as found at the Astoria field station. More extensive wet soil types in Willamette Valley such as Dayton and Amity silty clay loam have a pH of 5.0 to 5.4. The larger sizes of concrete pipe permit use of heavier aggregate, and where made to standard specifications, the fracture in breaking strength tests will frequently extend through the gravel.

Some improvements in preparation of cement and concrete for resistance to sulphates have followed increased knowledge of chemical reactions involved[2]. Aluminous cement forms more resistant pipes. However, it is not now available. On the other hand, concrete with less than 5 per cent tri-calcium aluminate is fairly resistant to alkali attack. Use of 4 per cent calcium chloride in concrete test pipes or blocks exposed in Medicine Lake proved helpful[3]. Less progress has been made in increasing resistance of concrete to acid.

It is concluded that, for wet soil types of nearly neutral reaction, concrete tile, particularly in larger sizes made of a rich dense homogenous mixture and well cured, or according to standard specifications for the American Society for Testing Materials, will serve as a satisfactory substitute for good burned clay drain tile. Although cement has been improved in recent years, the use of concrete drain pipe in strongly acid or alkaline soils, particularly the sulphate type, is still hazardous.

ACKNOWLEDGMENT: The author is grateful to C. E. Thomas for cooperation in making the breaking tests in 1940 and again in 1947; to Dr. Ray A. Pendleton for cooperation in statistical analyses of data, and to Supt. H. B. Howell for providing the pipe from the field lateral at the Astoria field station.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

W. L. POWERS is head, department of soils, drainage, and irrigation, Oregon Agricultural Experiment Station.

[1]Williams, G. M., and Furlong, Irving. Durability of Cement Drain Tile and Concrete in Alkali Soils (4th Progress Report, Technical Papers, U. S. Bureau of Standards No. 307).

[2]Lea, F. M., and Desch, C. H. The Action of Sulphate Waters on Portland Cement and Concrete. Arnold, London.

[3]Miller, D. G., and Manson, P. W. Tests of 106 Commercial Cements for Sulphate Resistance. Proc. A.S.T.M. 40:988.

[4]Miller, D. G. Choosing Drain Tile to Fit Your Soil. Minn. Ag. Ext. Folder 141, 1946.

Water Spreading

(Continued from page 76)

This has led to another problem — that of finding a suitable vegetation, preferably a grass which will grow in a partially submerged condition during the spreading operations and then aid in drying the soil rapidly down to the wilting point when the land is ready for a drying period. The grass desired should also have forage value so that some income may be obtained from the land besides its use as a spreading area. The grass must also have the ability to withstand droughts so as not to die out during periods when no water is available for spreading or irrigation.

In conclusion, it must be mentioned that while water spreading is a practical method of ground-water replenishment and can be used successfully in certain areas and under certain conditions, it like other conservation measures may have its limitations. There is little hope that it can ever be successfully utilized in areas underlain by continuous and relatively impervious hardpans, claypans, or other strata that provide the opportunity for perched water. In such areas the only hope is to locate the natural intake zone of the ground-water unit and confine the spreading to that zone, or penetrate the confining strata by wells or shafts. If the water is under artesian pressure by reason of being confined, the well method fails. Quality of water must also be taken into consideration, as a water with high sodium percentage is detrimental to infiltration. Extremely high sodium percentages have practically sealed the soil against any appreciable infiltration in San Joaquin Valley. A hard water is desirable for spreading, as in irrigation.

Only with careful and skillful planning under suitable physical conditions can water spreading be recommended as an economical water conservation venture.

Quantitative Measures of Hay Quality

(Continued from page 51)

While the theoretically possible combinations of variables in the problem are practically infinite, it seems likely that only a reasonably small number of factors and a limited range of values for each of these factors will actually prove significant.

From the standpoint of animal reactions it appears that the primary concerns are palatability, digestability, nutritive value, and other influences on consumption, health, and productivity.

From the standpoint of engineering interest the primary concerns are the influences of operating methods and equipment on feed quality. These are likewise measurable in terms of physical and chemical characteristics of the product.

Neither mow drying nor any other procedure or piece of haying equipment exerts a single uniform influence on milk yield or other feeding results. Feed production methods and feeding results can be related only by intelligent interpretation of their physical and chemical common denominator.

Chemically, the engineer is interested not only in total digestible nutrients, but in the influences on animal reactions obtained from the various types and amounts of proteins, starches, sugars, oils, vitamins, trace elements; poisons, medicinals, and indigestible ingredients in hay.

Among physical properties, the engineer is interested in animal reactions to variations in moisture content, fiber characteristics, fiber binders, free dust, separation of leaves from stems, stem length, and percentage distribution of important chemicals within the various plant parts.

Physical and chemical properties of hay, or in fact all animal feeds, are the intermediate quantitative data, the overlapping boundary between animal nutrition and engineering improvement of means and methods for producing, handling and storing feeds. The animal nutrition men can relate physical and chemical characteristics of feed to animal reactions to set up significant quantitative objectives and measures of feed quality. Then engineers can proceed on a sound basis to measure and improve the influence of production, harvesting, storage, and handling methods and equipment on the tangible, measurable, specific properties influencing feed value.

It seems likely that as this picture of the problem is presented clearly to more and more animal nutrition specialists, the needed cooperation, and ultimate quantitative definition of hay quality, will be forthcoming.

NEWS SECTION

A.S.A.E. Meetings Calendar

February 2 — CHICAGO SECTION, Builder's Club, Chicago.

February 6 and 7 — PACIFIC COAST SECTION, Yuma Air Base, Yuma, Ariz.

February 12 to 14 — SOUTHEAST SECTION, Hamilton Hotel, Washington, D. C.

February 14 — MICHIGAN AREA SECTION, Ethyl Corporation Research Laboratories, 1600 W. Eight Mile Road, Detroit.

March 4 — MINNESOTA SECTION, Coffman Memorial Union, University of Minnesota, (Minneapolis Campus).

March 26 and 27 — SOUTHWEST SECTION, Grim Hotel, Texarkana, Texas.

April 29 to May 1 — MISSOURI SECTION, Hotel Muehlebach, Kansas City, Mo.

June 21 to 24 — ANNUAL MEETING, Multnomah Hotel, Portland, Oregon.

October 21 and 22 — PACIFIC NORTHWEST SECTION, Columbia Gorge Hotel, Hood River, Ore.

December 13-15 — WINTER MEETING, Stevens Hotel, Chicago, Illinois.

A.S.A.E. Cooperating in Farm Work Simplification

THE Committee on Farm Work Simplification of the American Society of Agricultural Engineers, together with a similar committee of the American Farm Economic Association, is lending assistance in the publication of a manual on farm work simplification, the authors of which are Dr. L. M. Vaughan, USDA Extension Service, and Dr. L. S. Hardin, agricultural economics department, Purdue University. The Purdue Farm Work Simplification Laboratory is also one of the cooperators in this project.

The preparation of the manual was initiated at a conference of the two committees at the Purdue University last June, at which time the contents of the manual and the mechanics of its publication were worked out. The A.S.A.E. committee at a meeting at Chicago in December approved the revised contents of the manual and its publication by a well-known book publisher.

A second activity of the A.S.A.E. committee during the past year was a survey of the agricultural engineering department of the land-grant colleges to determine the amount of their cooperation in farm work simplification projects. Replies were received from the departments of 12 colleges and are summarized as follows:

1 The direction of the farm work simplification project and much of the work on it were found to be chiefly the responsibility of farm management specialists. Agricultural engineers cooperated to the extent to which they were in position to make contribution.

2 Agricultural engineers made a larger contribution to the cooperative work simplification studies than other subject-matter specialists.

3 Replies from all 12 departments indicated that it is desirable for agricultural engineers to have a major part in the project. They were in general agreement that farm management specialists are doing good work in simplifying present jobs, but that engineering techniques are needed to develop new equipment, arrangement of structures, and other methods to reduce or eliminate labor.

4 Replies from several states emphasized the need for studies covering commodities or types of farming, and not merely specific jobs.

5 Nine replies indicated that limitation of department funds had curtailed agricultural engineering participation; all 12 replies mentioned personnel as a limiting factor in participation in the project.

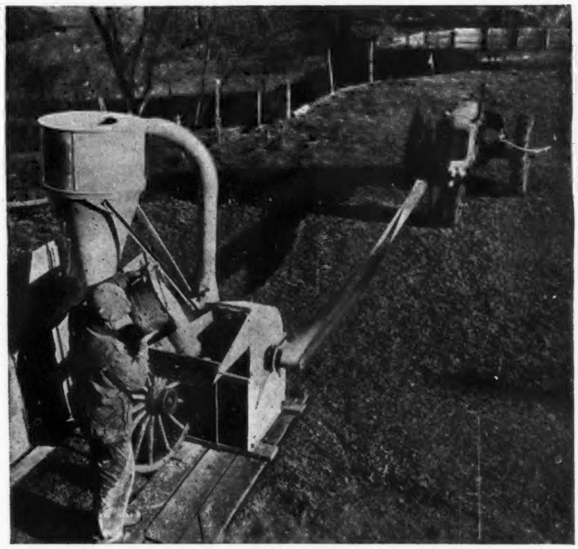
6 Several states requested that the national leadership of the project enlarge the scope of the study to include agricultural engineering.

New A-E Building on Way for LSU

THE latest word is that plans and specifications for a new agricultural engineering building at Louisiana State University are now in the hands of bidders; bids were to open early this month.

A recent addition to the agricultural engineering staff of LSU is Lawrence E. Creasy, a 1942 graduate of Virginia Polytechnic Institute. He was appointed as assistant agricultural engineer in research to carry on work in grass and weed control. An opening for another man in farm buildings research will shortly be filled.

(Continued on page 82)



NEWS SECTION

(Continued from page 80)

Minnesota Section Meeting

THE annual dinner meeting of the Minnesota Section of the A.S.A.E. will be held at 6:30 p. m., March 4, in Room 307-9 of the Coffman Memorial Union on the Minneapolis campus of the University of Minnesota. The speaker for the occasion will be A.S.A.E. President Geo. A. Reitz, whose address is titled "Opportunities for Agricultural Engineers." Reservations for the dinner ($2.00 per plate) should be made by Feb. 28 direct with P. W. Manson, Section secretary, Agricultural Engineering Bldg., University of Minnesota, University Farm, St. Paul. Both friends and members of A.S.A.E. are cordially invited to attend.

Kohler on Mission to Siam

KARL O. KOHLER, JR., chairman, Pacific Northwest Section, American Society of Agricultural Engineers, whose regular job is that of regional engineer of the U.S. Soil Conservation Service in the Pacific Northwest states, left the country December 31 for Siam where he will serve for a period of about three months as a member of a mission sent by the FAO of the United Nations.

Oklahoma A-E Department News

THREE new staff members and two technicians have recently been added to the agricultural engineering staff of Oklahoma A. & M. College. These include W. J. Oates, professor in charge of farm machinery research; C. L. Nelson, associate professor in charge of farm structures, and H. M. Haws, Jr., instructor in soil and water conservation (both teaching and research). A 40x80-foot structure with complete shop equipment including a brake dynamometer has been added to the department's facilities.

Personals of A.S.A.E. Members

John F. Benham recently accepted appointment as sales manager of the Dobbins Mfg. Co., Elkhart, Ind., manufacturers of sprayers, dusters, drinking fountains, etc. Until his appointment Mr. Benham was serving as executive secretary of the National Sprayer and Duster Assn. He formerly served on the agricultural extension service staff of Pennsylvania State College, as agricultural agent of the Pennsylvania Railroad, and as agricultural director of the American Feed Trade Assn.

D. M. Kinch has accepted appointment as assistant professor of agricultural engineering at Purdue University, in which capacity he will have charge of teaching and research work in the field of power and machinery. He previously held a similar position at Iowa State College.

Edwin F. Wadelton, executive engineer, John Deere-Lindemann Co., Yakima, Wash., was one of the winners in the farm machinery classification of the welding competition sponsored this year by the James F. Lincoln Arc Welding Foundation. He received a cash award of $100.00 for a paper he submitted comparing welded with riveted construction of a towed-type universal tool carrier.

New Literature

FIRE SAFETY ON THE FARM. Paper, 24 pages, 4x9 inches. Illustrated. National Board of Fire Underwriters (85 John St., New York 7, N. Y.).

Concise practical information on the amount of destruction due to fires, causes of farm fires, inspection, building construction, home fire protection, community fire protection, first aid treatment for scalds and burns, and recommended references.

TRENDS IN INDUSTRIAL RESEARCH AND PATENT PRACTICES. Paper, 80 pages, 6x8½ inches. National Association of Manufacturers (14 West 49th St., New York 20, New York).

Results of a survey by industries in 19 groups, with chapters on Industrial Research Summary, Industrial Research in the Various Industries, Patents and Products Resulting from Research Activities, Employees Inventions, and Independent or Outside Inventors. Important comparative data are tabulated.

New Federal and State Bulletins

Evaporation from Water Surfaces in California, subtitled "A Summary of Pan Records and Coefficients, 1881-1946," prepared by Arthur A. Young, California Department of Public Works Bulletin No. 54 (1947). This report is based on investigations conducted cooperatively by the Division of Water Resources, California Department of Public Works, and the Division of Irrigation and Water Conservation, Soil Conservation Service, USDA.

Biennial Report of the Vermont Public Service Commission (1945-46). Section two, pages 14-67, is devoted to rural electrification.

Tractors for India

To the Editor:

As regular subscribers and readers of your valued journal, Agricultural Engineering, we desire to convey to you our grateful acknowledgment and appreciation of the inspiring lead you are giving to the whole world on the subject of agricultural engineering.

You must no doubt be aware that India is at least one hundred years behind your country in the application of mechanization and scientific methods in agriculture, and it will be a revelation to you that some socalled agricultural engineers, appointed recently by the various provincial governments, have no conception of the modern tractor, let alone the more advanced agricultural machines now being used by your people. Not only this, but the government of India had put a virtual ban on the imports of all agricultural tractors from abroad, with the result that we had to lead an agitation against this ill-advised policy of the government. A press clipping of an article by the undersigned on this subject is enclosed herewith for your perusal. Fortunately our agitation has now succeeded, and the government of India have, in their press note dated December 12, 1947, removed these foolish restrictions. The flood gates are thus open for the unrestricted imports of all agricultural machines, including tractors. Our great country now looks forward to the American manufacturers to make available to her suitable machines and farm equipment to enable this predominantly agricultural country to be put on the road to mechanized agriculture.

Our firm deals in agricultural tractors and machines, and we seek to combine business with the advancement of Indian agriculture along mechanized lines. For this purpose we propose to organize an all-India movement in favor of mechanized methods in our agriculture. Fortunately we have the cooperation of the leading and enlightened agricultural engineers in this noble work, and we hope to report to you the progress we shall be making from time to time.

There is no doubt that as this movement gains strength, the demand for tractors and other modern agricultural machines will increase, and we wonder if you can help us by indicating possible sources in your country from where these can be readily imported. We consider light and medium tractors from 5 to 20 hp most suitable for Indian conditions, and if you could help us with the names and addresses of the manufacturers of tractors of these sizes, we shall be greatly obliged.

Dwarkadas J. Bhatia.

Bhatia Corporatioan, Bombay House,
Jubbulpore C.Ps. India

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Anderson, John W.—Experimental engineer, New Holland Machine Co., New Holland, Pa.

Baum, John A.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 141, Virginia Tech Station.

Beale, Carl M., Jr.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 70, Virginia Tech Station.

Beck, Robert E.—Agricultural counselor, Arkansas Power & Light Co. (Mail) Pine Bluff, Ark.

Bradford, Henry C., Jr.—Farm field engineer, Portland Cement Assn. (Mail) 1301 Capitol, National Bank Bldg., Austin, Tex.

Bristow, Gavin C.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 99, Virginia Tech Station.

Brock, Harold L.—Chief engineer, tractor section, commercial vehicle dept., Ford Motor Company. (Mail) P. O. Box 53 MB Station, Dearborn, Mich.

Campbell, J. J.—General manager, British Columbia Tractor Equipment, Ltd., 224 Industrial St., Vancouver, B.C., Canada.

Graham, Andrew L., Jr.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 240, Virginia Tech Station.

Johnson, John H.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 794, Virginia Tech Station.

Kenna, James H.—Captain, U. S. Army Air Force. (Mail) 6046 Ingleside Ave., Chicago 37, Ill.

Lall, Ganesh—Assistant agricultural engineer, agricultural department, Government of Bihar, Bihar, Patna, India. (Mail) 35/2 Gardanibag.

Leonard, John B.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 856.

Markel, John M.—Designing engineer, engineering department, J. I. Case Company. (Mail) Rockford, Ill. *(Continued on page 86)*

PROFESSIONAL DIRECTORY

Applicants for Membership

(Continued from page 84)

Mason, Richard M.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 965, Virginia Tech Station.

McFadden, E. J.—Agricultural engineering specialist (extension), Department of Agriculture and Forests, Khartoum, Anglo-Egyptian, Sudan, Africa.

Menon, R. G.—Assistant research agricultural engineer, Agricultural College and Research Institute, Lawley Road Post, Coimbatore, South India.

Mouat, G. C.—Lecturer in agricultural engineering, King's College, Newcastle-upon-Tyne, England.

Newton, Robert H.—Manager of dealer sales, The Lincoln Electric Co., 12818 Coit Rd., Cleveland, Ohio.

O'Connor, Trelyon W., Jr.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 1035, Virginia Tech Station.

Raught, Arthur V.—Project engineer, Dearborn Motors Corp. (Mail) 16249 Elizabeth St., Route 7, Birmingham, Mich.

Rhett, Douglas W.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 1104, Virginia Tech Station.

Smith, Easley S.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 835.

Smith, Randolph W.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 836, Virginia Tech Station.

Smythers, Horace M.—Student in agricultural engineering, Virginia Polytechnic Institute. (Mail) Woodlawn, Va.

Vassar, Basil M.—Student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 956.

Zengel, Laird J.—Chief engineer, Speed Sprayer Co., Division of Food Machinery Corp. (Mail) 1312 West Washington St., Orlando, Fla.

TRANSFER OF GRADE

Esmay, Merle L.—Assistant professor of agricultural engineering, Iowa State College, Ames, Iowa. (Junior Member to Member)

Geelan, Charles W.—Agricultural engineer, Soil Conservation Service, USDA. (Mail) San Saba, Texas. (Junior Member to Member)

Marti, George C.—Member, Constructors Rural de Mexico, S. A. Apartado 34, Linares, N.L., Mexico. (Junior Member to Member)

Searls, Dean L.—Manager, Adams Electrical Cooperative, Camp Point, Illinois. (Junior Member to Member)

Warner, D. F.—Instructor in agricultural engineering, Ohio State University, Columbus 10, Ohio. (Junior Member to Member)